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I-Connect007

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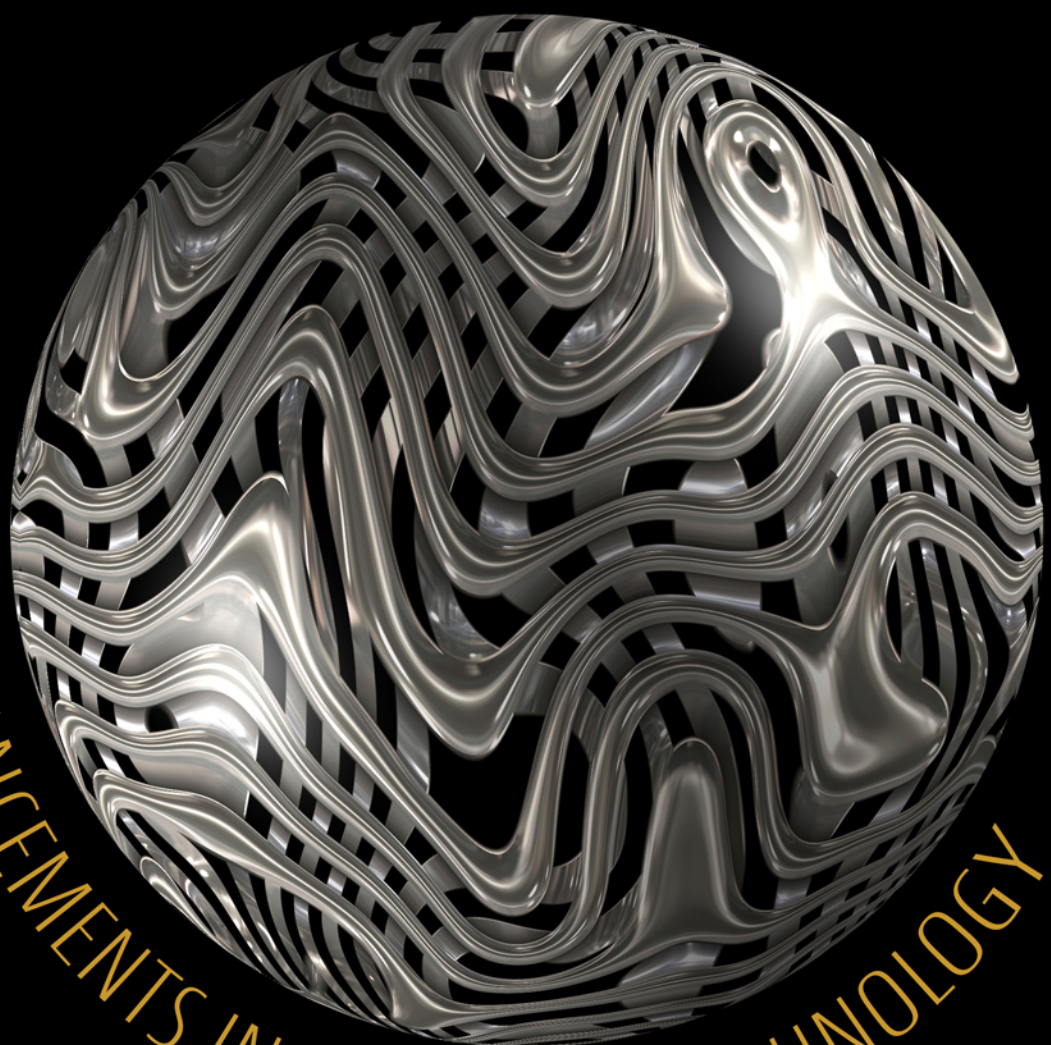

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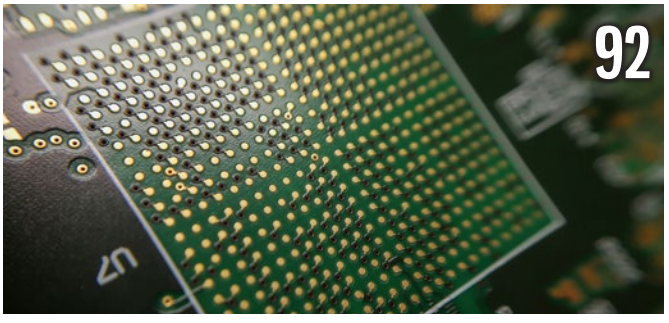

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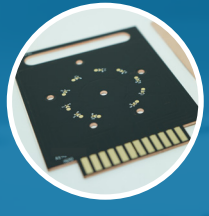
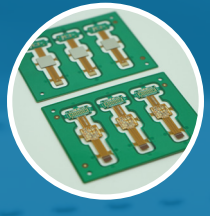

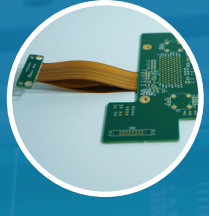
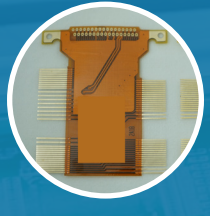
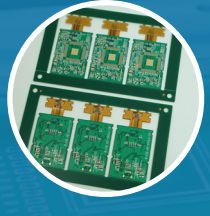

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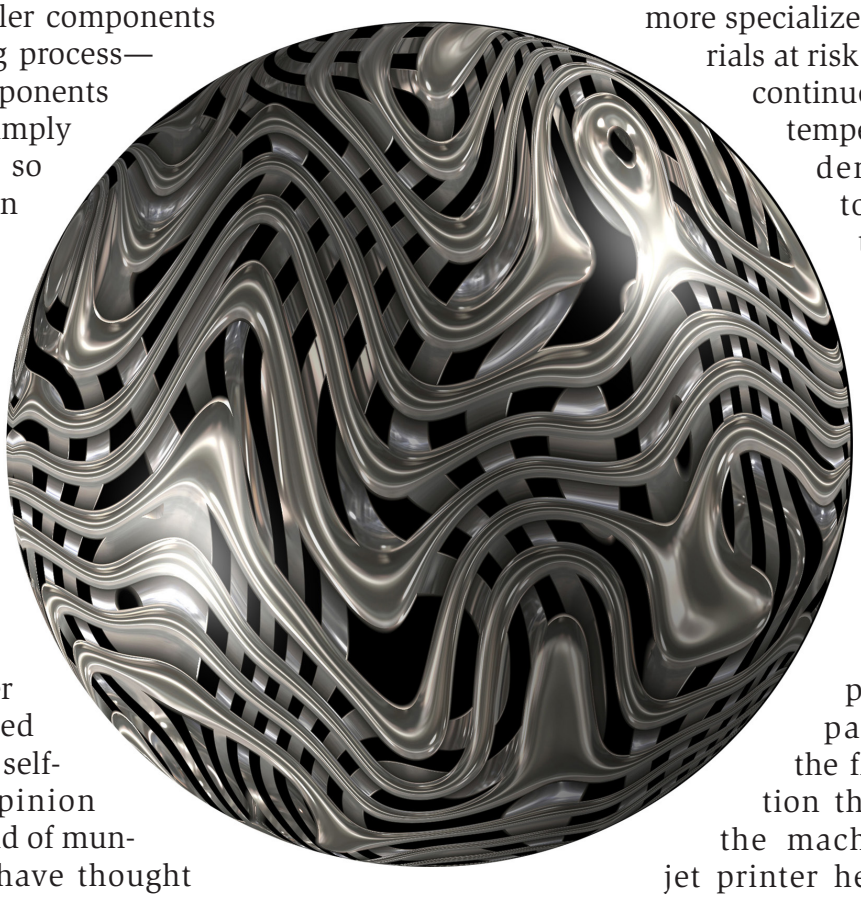
Advancements in Soldering Technology

Nolan's Notes
by Nolan Johnson, I-CONNECT007

Earlier in the year, *SMT007 Magazine* published an issue on "Fine Pitch." In that issue, we learned that the critical point for the manufacturing of electronics using smaller and smaller components was the soldering process—sticking the components to the board, simply put. There was so much information in this space that we decided to come back with a focus solely on the topic of solder technology.



"What?"you say. "Isn't solder rather boring?" Well, maybe. Even some of the solder experts expressed the endearingly self-deprecating opinion that solder is "kind of mundane." I would have thought the same thing until we started digging into the subject.

The solder market has fractured. Tin-lead still persists, but lead-free solders abound. ROHS lead-free solders require a higher temperature; this puts traditional components and packages at risk. ROHS solder temperatures change the dynamic for reflow operations. The higher temps also put some of the more specialized substrate materials at risk of damage. Work continues to create low-temperature ROHS solders—presumably to return to the temperatures and thresholds that are more traditional to our manufacturing processes.

Furthermore, smaller components and new packages changethe requirements put on the solder paste—especially the flux—not to mention the challenges on the machinery, stencils, jet printer heads, inspection machinery, and operator skillsets. It turns out that all of these aspects of solder are being pushed to improve.

A highlight for this issue was when Dartmouth's Ron Lasky, NovaCentrix's Stan

Farnsworth and Rudy Ghosh, Mycronic's Clemens Jargon, and Koh Young's Ray Wall and Brent Fischthal all converged on a theme: Each company and technology must cooperate to achieve the required results. Then, it was the work of Shea Engineering's Chrys Shea that wrapped up the advancements succinctly with the miniaturization test vehicle (MTV).

As ever, our columnists bring meaningful information and opinions to the table for discussion. Chris Ellis dives into customer support solutions, and Alfred Macha reviews why your business contingency plan may need some updating. Ray Prasad and Bob Wettermann both get technical, discussing reflow oven profiles and BGA assembly challenges.

As we go to print, most of us are still responding to COVID-19 by working from home, sheltering in place, etc. Many of us have been reminded of the value of the personal connection with other people through this process. Have you noticed, for example, how the people you do business with are more likely now to check on your safety, health, and level of coping?

It is our current mission and sincere intention to continue to bring you the latest news and information on the industry, even during this inflection point in our lives. We thank you for your readership and encourage you to reach out to us with your feedback, story suggestions, or submissions. This is a two-way conversation. We're here to tell you how the industry is doing, and we're here to tell the industry how YOU are doing. Let us know. Communication is the solder that holds us all together. **SMT007**

Nolan Johnson is managing editor of *SMT007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To contact Johnson, click here.

Tom Leighton on the Major Surge in Internet Traffic Triggered by Physical Distancing

With various physical distancing guidelines in place throughout the world as a means to curb the spread of COVID-19, the internet has experienced a dramatic spike in overall traffic. MIT Professor Tom Leighton is chief executive officer and co-founder of Akamai Technologies—a global content delivery network, cybersecurity, and cloud service.

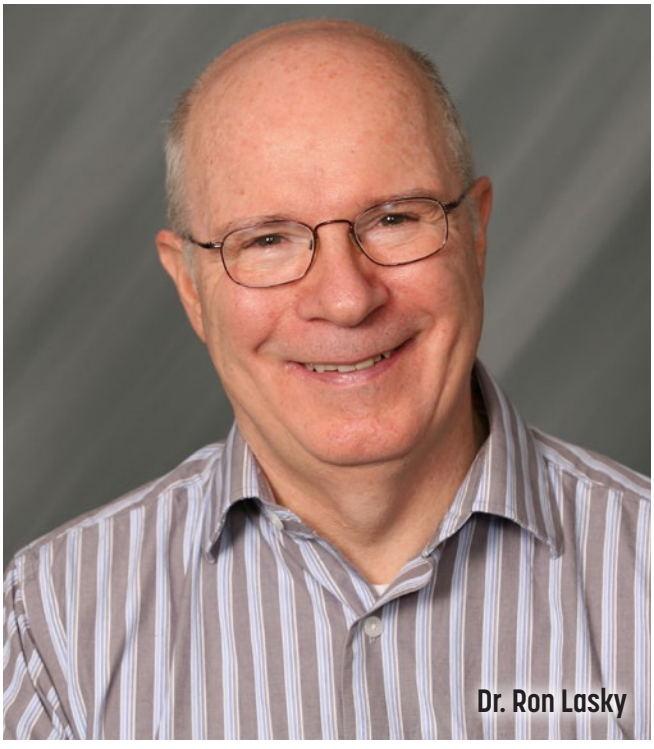
Q: How is the pandemic changing the way people use the internet?

A: The internet has become our lifeline as we face the challenges of working remotely, distance learning, and sheltering in place. We've already been doing many of these things online for years–the big difference now is that we are suddenly only doing them online.

It seems quite possible that our usage of the internet for nearly every facet of our lives will have increased permanently. Many more people may be working remotely even when offices reopen, the shift to virtual meetings may become the norm even when we can travel again, commerce may be conducted online even when we can return to shopping malls, and our usage of social media and video streaming could well be greater than ever before—even when it's okay to meet others in person.

(Source: MIT)

Dr. Ron Lasky: A Solder Alloy and Solder Paste Overview


Dr. Ron Lasky

Feature Interview by the I-Connect007 Editorial Team

The I-Connect007 editorial team spoke with Dr. Ron Lasky about why the world has not embraced some of the exciting alloys that companies like Indium Corporation have developed. He also provides an overview of solder alloys, including the difficulty of qualifying SAC305.

Nolan Johnson: Ron, thanks for joining us in this conversation. What's your role in the industry?

Dr. Ron Lasky: My day job is as a professor of engineering at Dartmouth, and I also work with Indium Corporation as a senior technologist.

Barry Matties: What do you teach?

Lasky: I teach engineering statistics. We have a program called a Master of Engineering Management (MEM). It's a graduate program for students that are engineers but would like to get into management. Most of the courses I teach are in this program. Half of the MEM program is taught by the MBA Tuck School of Management and the other half is taught by the engineering department. The topics that I focus on—and I have an additional program at Dartmouth on this—are Lean Six Sigma topics like process optimization, design of experiments, and statistical process control. I also teach a class on engineering statistics and one on optimizing manufacturing processes. I focus on one manufacturing process mostly, and that's electronic assembly because that's what I know the best.

The optimization work I do is quite general; it's not specific to solder paste. I developed a Lean Six Sigma program at Dartmouth that has become quite successful because—since Dartmouth is part of the Ivy league—people like the fact that they get a certificate in a yellow belt through master black belt that was granted by the school of engineering at Dartmouth College, but it isn't specific to electronic assembly.

Matties: When thinking of solder paste, is there a critical performance metric that you think is often neglected?

Lasky: Yes. There is something that's a critical performance metric in solder paste called "response to pause." If you have to shut the line down for some time because you have to put components on the pick-and-place machine or some other task, some solder pastes will stiffen up, and you can't use the first print. You have

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to print once, wipe the board, and print it again because the solder paste stiffens up. That's called a poor response to pause. A better solder paste—and this is one of the things my colleagues at Indium Corporation understand—has a good response to pause. In other words, you can leave the solder paste on the stencil for an hour or more, and it doesn't make a difference.

One customer changed to Indium Corporation's solder paste and no longer had to do this wiping of the board when they stopped the line every couple of hours to do something. In the past, each of these times, the paste would stiffen, and they had do to the "print-and-wipe" procedure. At the end of the day, it ended up being 20 minutes or more of lost production in an eight-hour shift; it was a bigger deal than might first appear. The new solder paste improved their productivity a couple of percentage points, but it improved their profitability 8–9%. With cost estimating software I had developed, I was able to calculate all this, and we ended up writing a paper on the topic.

Feinberg: Do you see a significant change in the volume of solder that is being used as a percentage basis—not by tonnage or anything—for a solder paste versus bar solder for wave soldering?

Lasky: Solder paste has become more dominant, and that's the case because certainly surface-mount technology, for a lot of our products, is the only thing used. I don't think there are any cellphones that use wave soldering.

Feinberg: No, I wouldn't think so at all.

Lasky: But don't discount bar solder. Twenty-five years ago, some people said, "Wave soldering and through-hole are going to go away. We shouldn't even pay attention to those," but that's nonsense. They're not going to go away probably ever.

Feinberg: One of the things with through-hole is that with the change in the last decade to lead-free solder, the flexibility of the solder has reduced significantly. And when you have a component that's mounted through a through-hole and then soldered versus placed on a pad and then soldered, the reliability is significantly better with the through-hole.

This behavior hasn't mattered so much until the reliability needs have increased, which they have increased significantly in the last 36 months, thanks to autonomous driving and the volume of electronics in transportation. That may be slowing down the decrease in wave soldering, although—from an economic standpoint—it makes no sense. We're kind of at a crossroads right now.

Lasky: I have to push back a little bit on that. I would agree that one of the reasons wave soldering is not going to go away is some of our electronics products have a lot of plugs. Some of those plugs want through-hole for mechanical strength.

Feinberg: That's true.

Lasky: A lot of the components that are made that are critical for autonomous driving only come in surface mount formats because you can't beat SMT's interconnectivity. If somebody said, "We want to make an Intel microprocessor be through-hole," it wouldn't be possible because there are too many interconnects, and you can't make through-holes that small. I agree with most of your thoughts on through-hole, but we're going to have to make surface-mount reliable enough for situations like this.

Feinberg: Some military components are going back to leaded solder. It's a temporary fix, but it is a fix in some cases.

Lasky: They never had to go lead-free, of course, but a problem for the military applications is getting something in a tin-lead format.

Matties: When you look at the solder paste arena, what do you think the critical knowledge is that people need to have today?

Lasky: It doesn't appear to me that new alloys are going to be embraced by the industry for

solder paste, and that's a shame. I'll tell you what I mean by new alloys. Today, 75–80% of the solder paste in the world is lead-free, and a pretty high percentage of that is SAC305. I don't want to hurt anybody's feelings, but I've given talks on SAC305 for an hour and had somebody come up afterward and ask me what SAC305 is.

With SAC305, the 30 is 3.0% silver, and then the 5 is 0.5% copper, and the balance of 96.5% is tin. The remainder of the lead-free is mostly SAC105, which has lower silver, which is good to save a little money on the silver. The SAC105 is mostly in solder balls for BGAs. My point is companies like Indium Corporation have performed a lot of work developing alloys that would have much less silver than the 3% in SAC305. They put in small quantities of other elements, and by doing this, they have come up with some alloys that are better than SAC305 in both drop shock—to protect your cellphone when you drop it—and thermal cycle—to protect your computer from the thermal-mechanical stress generated by turning it on and off. Yet the industry hasn't embraced them.

If you think about it, there's a logical reason. It costs a lot of money to qualify a new solder alloy, especially if you're a company that wants a reputation for reliability. And some of the cellphone and PC companies, especially companies that would be producing something that's mission-critical, need a reliable solder. There was so much pain in qualifying SAC305 that even if there is something that promises to be better, SAC305 is good enough. Their feeling—and they may be right—is if we embrace this new alloy, it may be better in many respects, but SAC305 is the devil we know. The newer alloys might have something that doesn't even come out, maybe in the tests.

The world has not embraced some of the exciting alloys that companies like Indium Corporation have come up with. I'm sure there are niche customers that buy some of these, but SAC305 is dominant. I don't see that changing because it's pretty good. The thing that changes all the time is not the alloy so much. Again, I don't want to make it sound like there isn't any interest in these other niche alloys, but the thing that changes all the time is the development of the new flux vehicles to improve the performance of the solder paste. That's happening all the time and continues.

I'll give you an example of some things that have happened in solder paste in the last 10 years that continue to happen. Ten years ago, the head-in-pillow defect for BGA packages reared its ugly head, and there were all sorts of changes in processes that people developed to try to minimize this failure mode. The companies that make solder paste quickly jumped on the bandwagon and tried to develop solder pastes that would minimize or eliminate the head-in-pillow defect. In one case, an assembler had 7% head-in-pillow defects. By changing to a solder paste that was designed to minimize the head-in-pillow defect, it went away.

The same was true for the graping defect. The latest thing, in the last five years, has been a lot of interest in minimizing voiding. Indium Corporation has developed solder pastes that dramatically minimized voiding. Of course, one of the challenges is that there isn't usually one solder paste that will be better in all respects. If voiding is your issue, the best paste to control voiding may not be quite as strong as another solder paste is in eliminating the head-in-pillow defect or eliminating graping or that sort of thing. But the work that the solder paste manufacturers have done to address defects, in my opinion, has been breathtaking and can be attributed to the scientists and engineers that study and improve solder pastes. But I don't see a mainstream leaving of the alloy SAC305.

The latest thing, in the last five years, has been a lot of interest in minimizing voiding.

I should mention two alloys that are important exceptions to SAC305. One of the pains of lead-free solder is the cost of silver, and the 3% silver in SAC305 makes it expensive—especially for bar solder for wave soldering. If you look at a wave solder pot—which could have

1,000 kilograms of solder in it—and you are using SAC305, that much solder would cost as much as a car! Some metallurgists developed a very high tin content around 99.3% tin with 0.7% copper solder for wave soldering. Initially, that didn't work very well, but metallurgists found that if they put a small amount of nickel in it—say 0.06%—it made the solder perform much better. For wave soldering, that alloy—99.3% tin and 0.7% solder with a trace of nickel—has been a real winner for the wave solder market.

One other thing that that's emerging is there are a few disadvantages to lead-free solder, such as the higher cost and higher melting temperature. Tin-lead solder melts at 183°C, and lead-free solder melts at a little less than 220°C. That's quite a temperature increase. iNEMI and others have made a large effort to develop a low-temperature solder alloy, and the main candidate is tin-bismuth. This melts at a lower temperature than tin-lead solder, about 138°C.

The main reason to choose tin-bismuth is the lower temperature, which is less stressful on the components when reflow soldering to a board. However, bismuth-tin has a disadvantage in that it's brittle. If you use it for a mainframe computer, it's probably okay, as it performs well in thermal cycling. IBM used an alloy like that for many years. But, if you use it in a cellphone, you have to improve the drop shock performance. A lot of this iNEMI project is to try to modify the tin-bismuth alloy to make it so that it performs better in drop shock and maybe even with some help like using a polymer coating to strengthen the solder joints.

Feinberg: Would nickel take away a little bit of that brittleness?

Lasky: No. We're talking about a tin-bismuth solder. An addition of nickel will not benefit this solder. It's 99.3% tin and 0.7% copper solder that a small amount of nickel helps. The main disadvantage for that solder is that it requires an even higher temperature, up to 227°C to melt. And when it cools, there's like a frostiness in the solder joint. Not only does it look bad, but it could have reliability implications. When you put this little bit of nickel in, the frostiness goes away.

Feinberg: When it comes to lead-free solder, most people don't realize that there are indeed some negatives to it.

Lasky: The big issue when going to lead-free was a lot of people thought the negatives were almost too much; perhaps it wasn't going to work from a reliability perspective. Researchers spent hundreds of millions of dollars, trying to find an alloy to replace tin-lead that would be acceptable that would melt at approximately the same temperature, but they couldn't do it. Indium Corporation and others had developed alloys that melt at exactly 183°C, but for several reasons, they ended up not being widely accepted. Thus, after hundreds of millions of dollars of research worldwide, the SAC alloys pretty much ended up being the only choice that was reasonable in all respects.

After hundreds of millions of dollars of research worldwide, the SAC alloys pretty much ended up being the only choice that was reasonable in all respects.

When all the dust has settled, we would not have a modern cellphone if it wasn't for lead-free solder because it does not wet as well as tin-lead solder. This initially supposed drawback of lead-free solder has enabled closer spacings of the pads without the short-circuiting that tin-lead solder would cause. In other words, tin-lead solder wets so well that it would short the pads out. What seems like a disadvantage in that lead-free solder doesn't


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wet as well ends up becoming an advantage. Because the reason being that an electronics designer can space the pads closer in your cellphone and get more components crammed in. However, that was an unexpected benefit that few people recognize, even today.

Feinberg: Let me get back to my question about the nickel. The largest cost for the assembly industry is recycling the dross, and many assemblers don't realize until someone sits down with a pen and pencil and shows them. Does the nickel do anything to reduce the percentage of dross that's created?

Lasky: Yes, it does. Let me state that I'm not as knowledgeable in this as I am solder paste, but I believe they also put a small amount of some other elements in like germanium. We're talking like something like 0.05%; it's not even close to 1%. If you don't get the amount right and you put too much in, it won't work. It must be very precise. For wave soldering, I believe these alloys with trace metals, such as nickel and germanium, have become regularly used. Again, my expertise is more in solder paste.

Johnson: I'm getting the sense that there is fracturing in the formulations, a period of developing specialized formulations to fix particular problems.

Lasky: It's important to point here that it's not in the metal alloys; it's in the manufacturing of solder paste to try to solve different assembly problems. The point I was making is you would like to have one solder paste that would solve all of the different assembly problems, but that is likely impossible. As an example, a solder paste might be developed that's good in solving the voiding problem on QFNs. It can be developed so that it's quite good in other aspects, but if there's a company that their main issue is a head-in-pillow defect in BGAs, there's probably another solder paste that's a little bit better in that regard and maybe not quite as good in voiding. But this company that's having the head-in-pillow problem doesn't have a voiding problem. It's a fact of life that any type of manufacturing process is an optimization process. It's very difficult to make one solder paste that is the best at everything.

Johnson: Taking us back to the certification issue you were talking about earlier. If there are a variety of solder paste formulations out there, and selecting the right one for your manufacturing challenges is part of the process, how do you do that?

Lasky: One of the things that should be a blessing to users is solder suppliers who have tech service engineers. If a customer has a problem, the first thing they should do is get on the phone and talk to their solder paste supplier's engineers because they solve these problems every day. If you say, "I'm having a problem with a head-in-pillow defect," the tech services person will ask you, "Which of our solder pastes are using?" If you say, "I'm using formula D," they'll respond, "That's the one that's made more for voiding, while formula B is the one that's best for using on the head-in-pillow defect." Often, you can solve your problem with a phone call instead of a lot of experimentation.

I always suggest to people that when they have assembly problems, first call your materials or equipment supplier's technical experts. If you're having trouble with placement or stencil printing, call your placement equipment or stencil printing company because these people do this work every day with customers all over the world, so they have seen about everything. In your company, you only see one thing. Use your suppliers and technical experts for both equipment and materials.

Matties: Dr. Ron, thank you for your time today. We greatly appreciate it.

Johnson: Ron, thank you. You've given us a lot to follow up on.

Lasky: Thanks so much. SMT007

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How Engineers Can Use SPI Tools for Verification

Feature Interview by Nolan Johnson
I-CONNECT007

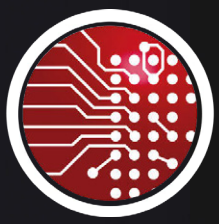
Koh Young's Ray Welch and Brent Fischthal detail how engineers can work with SPI tools to verify how small they can go in component size with their solder paste application, and how the company's SPI equipment is helping not only to verify but also to help drive the development collaboration between solder paste and stencil printer manufacturers, and inspection tools and software.

Nolan Johnson: What trends and advancements do you see right now in solder and solder application in the manufacturing process?

Ray Welch: You may be familiar with Chrys Shea's new SMTA miniaturization test vehicle (MTV). I've worked with her and Indium recently, using this new test vehicle; she's trying to give people a tool to be able to challenge themselves to print smaller and smaller. That test vehicle goes down to 008004 chip components. I don't know of any customers that we have that are printing that small yet, in terms of chip components, but we have people who are printing near wafer-level prints for RF devices and cellphones. I was working with Indium because they were trying to verify their new pastes and how well they perform for the smaller parts. We've been working with our industry partners to help them understand how to use our SPI to be able to get accurate measurements for the smaller and smaller parts.

Johnson: This sounds like a bit of back and forth, building operator skillsets while also verifying that the machines can do that kind of feature size.

Welch: Yes, Chrys and I went to MPM in Hopkinton, Massachusetts. Indium was there, and they wanted to verify several of their new pastes for printing the smallest part at this time. The challenge for us was to make sure that we could measure such small parts, and we can. We performed a DOE, and everything worked out quite well, both in terms of solder paste performance and the Koh Young SPI system. Since then, I helped Indium remotely



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to use the Koh Young SPI system they have at their shop to verify their pastes. Again, I don't have any end-users that I know of using the 008004 parts yet, but we're giving them a system via the aSPIre3 and 10-micron lens resolution to be able to inspect those smaller parts.

Ray Welch

Johnson: The equipment and material suppliers have proven that they can deliver the functionality needed for the current smallest parts of the market, even if people may not be using them yet.

Welch: Yes, but the caveat to that is that whenever we do something in the lab with a bunch of engineers involved, you can oftentimes get very good results. You don't always get those results when you put it into manufacturing.

Since joining Koh Young in April 2016, I've visited about 50 customers delivering our two- to three-day SPI and print process characterization training program. People can't print those small parts until they improve the discipline of their process. For a number of customers, it seems the operators have hijacked the SPI process. The engineers aren't there or don't like to go out to the line except when there are serious issues. Many times, the process engineers aren't watching over the process like they should or don't know the process as well as they should, so there will be a reality check when they move to smaller and smaller parts.

Johnson: Is it fair to say that the control of the inspection processes on the manufacturing floor with the manufacturing operators who are under one set of incentives for part of their job that may be at odds with being accurate and getting good yields, and not having field failures later?

Welch: That's correct. A lot of engineers don't want to be called to the line if they don't have to be, so they leave it to the operators or process technicians. If they don't visit often enough, then the operators are going to hijack the process and do whatever they think is right. I've stood there many times watching an operator pass boards that should have been failed. I call those "wall of shame" examples, where they've opened up the inspection tolerances, or the operators are doing whatever they want to do, and then products are escaping SPI. They have a great tool in SPI, but they're not using the tool as best they can. That will definitely be a challenge when they get to the smaller parts.

Johnson: Let's paint a possible scenario then. Right now, maybe it's working, they're getting by, and they're doing okay purely by accident. As they move to smaller and smaller parts, that's going to break at some point. What should they be looking for, and how do you fix it?

Welch: SPI reveals the sins of the process. I'm trying to teach people how to use the tool as best they can, as well as tools and techniques for analyzing the data. It's also important not to be driven by just defects but by the parametric data that shows them how well the process is performing in terms of process capability. Then, it's about improving the process and not just trying to turn off SPI defects.

Johnson: This must be a challenge. You're providing products that could help customers see fewer field failures and better yield, but by default, it's exposing the dirty laundry in the process. That can be potentially embarrassing or even job threatening. How do you change that from a threat to a benefit?

Brent Fischthal: When Ray delivers these engagements to our customers, he helps them

understand how to use SPI. SPI has been around for a while, but not everyone uses it the right way. Sometimes, bad habits form. This specific class resets those bad habits. We're educating them on how to implement the best practices. Ray does find that wrong processes have been implemented, or that operators are using it incorrectly or sub-optimally. Everybody who has experienced Ray's class has come away appreciative of the insight they've gained. More importantly, most change the way they've been doing things right away.

Brent Fischthal

Johnson: If you don't have support from the C-level executives, then you may encounter managers who have a very different set of objectives.

Fischthal: Most people want to build the best products they can and not have to worry about rework or field failures because an operator was incorrectly using the SPI.

Welch: Yes, but as Nolan was saying, some people have a different objective or performance goals to meet, so even though the engineers might want to make improvements, sometimes they're held back because the line production doesn't give them the time. The engineers need to be given the time and line availability to identify issues and opportunities for improvement and then implement the necessary actions. Right now, the biggest thing I see is management often wants to get down to one operator per line and no engineers on the line. That's not going to work very well when your process isn't robust—a hands-off process—and none of them are there right now.

Johnson: When you talk to a customer about putting Koh Young equipment into their line, they're already motivated to some level and have invited you. They've had some sort of a compelling event that caused them to decide that they need to make this change. Are you at liberty to share some of those compelling events?

Fischthal: We've seen some people that want to look at their paste because they realize if they are able to fix the process in the beginning, it's much better than adding process steps at the end to check after reflow. We've had people that will build products with insufficient solder, bridging, or other common printer errors that happen in an uncontrolled process. These manifest as quality issues on the other end of the line. Then, they will bring in an SPI. In general, there's a shift to believing that if they can fix it at the front, it saves them at the end. Which is true.

Johnson: Your training materials contain discussion about changing the thinking: ongoing process monitoring more than inspection at the end.

Welch: Most people are using SPI as just a go/no go system, and even for the brightest engineers, there might be only a few who dig in a little deeper, but not necessarily day in, day out. I've tried to teach them how to use the tool better, as well as use it for developing more robust processes—not just fixing day-to-day issues. When I go to some of the big operations, the operations people control the line. Sometimes, it's hard to get time on the line to make even simple improvements. I say, "Let's make the change now," and they say, "I can't change it now." If you can't change it then, it may not ever get done. It's a cultural thing from the top down.

Johnson: Based on all the developments with the digital factory, is there an opportunity to

use the SPI information to keep things like solder paste jetting or solder paste application in compliance within tolerances?

Welch: To a limit. Our Koh Young Process Optimizer (KPO) now has various printers that have opened up the key print parameters so that we can take control of the printer. First, we do it to perform a real DOE to try to optimize the print parameters. Then, we monitor the process via SPI and fine-tune the print parameters in real-time to stay in compliance. There are still other factors, but at least it's trying to keep the process in control. There's another module in the KPO tool that looks for patterns and variations in volume across the board. We are trying to maintain or achieve some real-time control of the printing process through the three parameters of print speed and pressure and separation speed. But you still have to practice good, sound printing process practices on the part of the operator.

We are trying to maintain or achieve some real-time control of the printing process through the three parameters of print speed and pressure and separation speed.

Johnson: Part of your presentation talks about making sure that you're programming your tests appropriately and testing for the right thing. That strongly implies that good testing involves a more thorough thought process while programming the tests. How much skill level is involved in that work? What kind of training is required to be a good programmer with the Koh Young SPI equipment?

Welch: The level can be a good process tech up to an engineer. It can't be an operator, per se, unless they're a super operator, but a process tech and above. Every customer I've visited has an issue with programs. Often, the people who were initially trained by Koh Young have moved on. There has to be discipline in the program itself. I usually start by looking at the programs and making sure that the SPI system is set up correctly, so you know you're getting good, valid results. Then, we can talk more about characterizing the process, which plays back into the printer itself.

Johnson: Isn't what you described an HR problem?

Welch: Sometimes, large organizations have the CAD or test engineering people create the SPI programs, but that person may have no connection with the print process itself. The person who creates the program may never see it on the line, or the people on the line don't understand programming themselves, so there's a disconnect. Oftentimes, when I go there, I'll see something on the screen, and I'll say, "Do you see that?" and the engineers or process technicians don't even know what I'm talking about. It reveals the sins of the process, which may be the sins of them creating a program or something with the way they're doing SPI.

Johnson: It is the operator or technician attrition on the floor that I was flagging as an HR department issue. The trained staff are gone, and somebody who's untrained is now in charge. There's where I point back at HR to make sure that that company has the appropriate training programs in place for the people taking over the job.

Welch: I agree. I've seen places in manufacturing where they're short a person or two, and they walk someone in front of a machine and say, "Run this machine," without good training. Otherwise, the person offering the training candidate might not realize the skill or discipline required to run something like an SPI system, and certainly our AOI systems, which are far more complicated than SPI. Sometimes, they give us the wrong person to train.

Johnson: There seems to be a circle of development here. You're working very closely with the solder paste application companies and the solder paste manufacturers to make sure that you're all communicating appropriately here. We started by talking about how you've proven down to the smallest currently manufacturable component sizes, and that was working in concert with multiple vendors in this space. How active or how aggressive are you all in working together?

Welch: Pretty well. I've done a fair amount of work with Chrys Shea now, and I've been to MPM many times, mostly as part of our KPO development and testing. I think we all work very well together. Some of the printer and solder paste companies have our systems so that they can do SPI in their labs.

Johnson: From your perspective, are most of the participants playing well together?

Fischthal: We've had some pretty good success with collaboration across the printer suppliers. From the SPI standpoint, we have a couple of different ways we can improve the closed-loop communication from basic correction to AI-powered process optimization. When we look at what our KPO is doing, we're working with the major providers, so we're all working together with them to come up with some powerful solutions. Everybody is striving to improve the process.

Johnson: Components are going to go smaller, and there are going to be challenges. Where is the spot that needs the most work right now?

Welch: I'd say miniaturization. The biggest challenge is inspecting those near-wafer level solder bumps on the little RF devices that go in cellphones and such. They're printing down to stencil apertures of about 3.7 mils with one-mil stencils. They're still being printed with traditional printers; our partners are working with our joint customers to try to get the best possible print process and the best possible solder paste and stencil technology.

Johnson: Thank you, gentlemen.

Welch: Anytime, sunshine.

Fischthal: You're welcome. Thank you very much. SMT007

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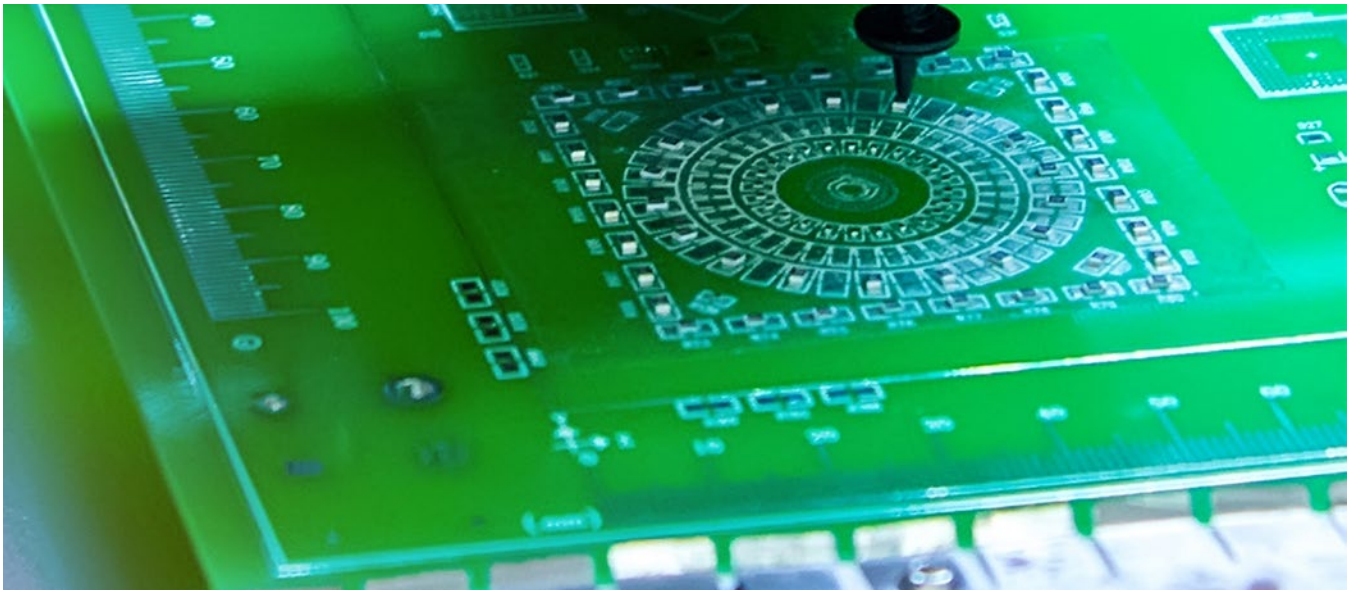

High-reliability, Low-temperature Solder Alloys

Feature by Pritha Choudhury, Morgana Ribas, Raghu Raj Rangaraju, and Siuli Sarkar
MACDERMID ALPHA ELECTRONICS SOLUTIONS

Increased digitalization and greater connectivity have been driving miniaturization and more complex and integrated designs in electronics. As the real estate on PCBs shrinks, so does the size of packages. However, the drive for finding design solutions for increased performance has continued to expand. The solder joint is an essential part of assemblies for electronic devices as it provides electrical, thermal, and mechanical connections. Therefore, soldering materials have been evolving to enable such a technological revolution.

Restrictions in using lead in soldering materials in the early 2000s have propelled the electronics industry towards the widespread use of lead-free soldering materials. Since then, the requirement for solder alloys with higher thermal and mechanical reliability is the most important technology driver for designing new soldering materials. Low-temperature solders (LTS) are currently being considered for a variety of assembly needs. They have the potential to increase long-term reliability by reducing thermal exposure, to reduce overall materials cost by using low-Tg PCBs and low-temperature compatible components and its carbon footprint. Using low-temperature solders has also been shown to lower energy consumption, to reduce dynamic warpage of BGA packages and PCBs, to increase assembly yields, and to lower or eliminate non-wetting open and head-on-pillow defects [1, 2]. Indeed, dynamic warpage is a serious concern for PoP bottom and PoP memory packages, as they can cause serious soldering defects, such as non-wet opens, solder bridging, head-on-pillow, and non-contact opens [1, 3]. Extensive studies have shown that such warpage is highly dependent on the reflow temperature and can be drastically reduced to acceptable levels by keeping the soldering temperature below 200°C [1].

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Next-generation LTS Alloys

It is important to note that just reducing the melting point of an alloy is not enough for delivering high-reliability solutions for such technical challenges. For example, the eutectic 42Sn58Bi alloy would be a logical choice, given its melting point at 138°C, but its lower ductility and poor thermal fatigue life do not come close to the currently used SAC305 alloy. Its Bi-rich phase causes embrittlement, making eutectic 42Sn58Bi prone to brittle fracture under high strain rate conditions [4]. Materials suppliers and industry consortia, such as iNEMI, have been extensively working on developing and testing new low-temperature alloys to fulfill such requirements [5–11].

The addition of silver has been one of the most common ways to modify the microstructure and resulting properties of the eutectic SnBi alloy. MacDermid Alpha Electronics Solutions's extensive research on solder alloys went beyond that and worked on developing a comprehensive family of low-temperature solders with improved thermal and mechanical reliability. SBX02 solder (an Ag-free eutectic SnBi with micro-additives) has been shown to have significantly higher mechanical shock and thermal cycling properties than commonly known 42Sn58Bi and 42Sn57.6Bi0.4Ag alloys [8]. More recently, HRL1 (a non-eutectic SnBi solder with about 2 wt.% performance additives) has shown superior drop shock and thermal cycling performance. This new LTS alloy combines an optimal level of Bi and the right combination of alloying additions to improve its thermal and mechanical reliability, as shown herein.

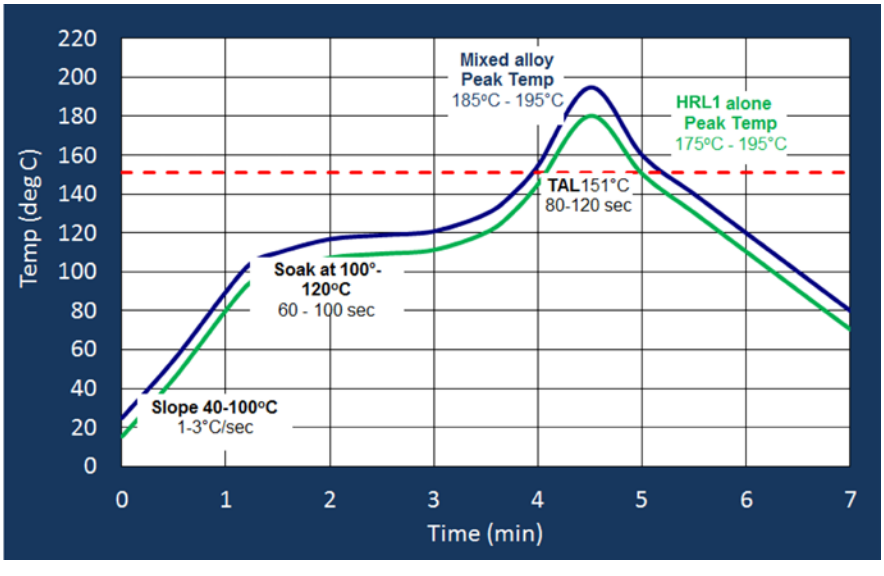

Figure 1: Reflow profile for the HRL1 low-temperature solder.

LTS Paste and Assembly

The selected alloys were processed into IPC type 4 powders and mixed into a paste using an appropriate paste flux for further solder joint thermal and mechanical reliability evaluation. The reflow profile used for assembling the test vehicles with HRL1 solder paste is shown in Figure 1. Soaking was done at 100–120°C for 60–90 seconds. The time above liquidus (TAL) was 35–40 seconds, while the peak reflow temperature was 185–190°C. All the BGAs evaluated had SAC305 balls.

Bulk Alloy Properties

A combination of solid solution strengthening and precipitation/dispersion hardening can be used to improve the mechanical strength of metallic Sn. Elements such as Bi, In, and Sb have relatively high solubility in Sn, forming a solid solution, whereas other elements such as Ag and Cu have little solubility in Sn-Bi and, among other elements, can be used in minor additions for their strengthening. Bulk alloy properties can provide insightful information about solder joint mechanical and thermal fatigue resistance, going beyond the microstructure observations.

Table 1 shows some key physical properties of eutectic 42Sn58Bi, HRL1, and SAC305 alloys. Solidus and liquidus temperatures of high purity 42Sn58Bi alloys are identical (i.e., eutectic) and about 138°C. As per the Sn-Bi phase diagram, reducing the Bi content below the 58 wt.% corresponding to the eutectic point, results in higher liquidus temperature, depending on micro-alloying additions. In the case of alloy HRL1, the solidus and liquidus temperatures are 138°C and 151°C, respectively.

Alloy	Sn-58Bi	HRL1	SAC305
Solidus Temperature (°C)	138	138	217
Liquidus Temperature (°C)	138	151	220
Density (g/cm^3)	8.54	8.44	7.43
CTE (µm/m. °C)	18.5[1)]	20.8[1)]	24.8[2)]
UTS (MPa)	63.6	62.2	44.5
Yield Strength (MPa)	53.0	37.5	39.6
Elongation (%)	69.0	54.0	51.6
UTS 75°C (MPa)	NA [3)]	27.2	27.6
Yield Strength 75°C (MPa)	NA [3)]	21.0	21.2
Elongation 75°C (%)	NA [3)]	94.1	68.9
Young's Modulus (GPa)	39.0	41.4	49.8
Poisson Ratio	0.33	0.36	0.36
Creep Strength 80°C (hrs)	21.0	26.0	NA

Table 1: Key bulk alloy properties. (Notes: 1) CTE between 25 and 80°C, 2) CTE between 25 and °C, 3) Sample deformed at °C.

Additionally, the DSC curve of HRL1 shows a 79.7% conversion into a liquid at 139°C and 99% at 144°C [10]. The densities of 42Sn58Bi and HRL1 alloys are higher than SAC305, as Bi density is considerably higher than Sn. The linear coefficient of thermal expansion (CTE) of HRL1 alloys is somewhere in between 42Sn58Bi and SAC305.

At room temperature, both Sn-Bi alloys have considerably higher ultimate tensile strength (UTS) than SAC305. However, HRL1 alloy yield strength and elongation are similar to those of SAC305. Comparatively, the eutectic 42Sn58Bi higher yield strength exemplifies its brittle nature. Tensile data of 42Sn58Bi at 75°C is not available, as the tensile samples started deforming and slipping from the testing grips. However, at 75°C, HRL1 tensile and yield strength still match SAC305 performance, which is a strong indication of HRL1 improved mechanical and thermal strength.

Creep tests of the bulk alloys were performed using a constant load (150 N) at 80°C. This type of test offers an opportunity for gauging the thermo-mechanical properties of solder joints before any assembly takes place. The total time until rupture, also called creep strength, of HRL1 is 30% higher than in the eutectic 42Sn58Bi, providing additional evidence of HRL1 improved resistance to mechanical and thermal stresses.

Mechanical and Thermal Reliability

Portable and handheld devices have quickly become part of our daily lives and, consequently, resistance to drop and shock turned into a must-have property of solders used in such devices. Since the testing of actual electronic devices is quite cumbersome and expensive, proxy tests (such as the JESD22-B111 standard) can be used instead. JEDEC's service condition B (1500 Gs, 0.5 ms duration, and half-sine pulse) is probably the most common drop shock test at the board level and serves as a reference for the results presented later.

Reducing the Bi content below 58 wt.% can effectively improve the alloy ductility while maintaining its strength and results in improved drop shock performance, as shown in Figure 2 [10]. However, Sn-Bi alloys with 40 wt.% Bi or lower have liquidus temperatures above 178°C and would require reflow tem-

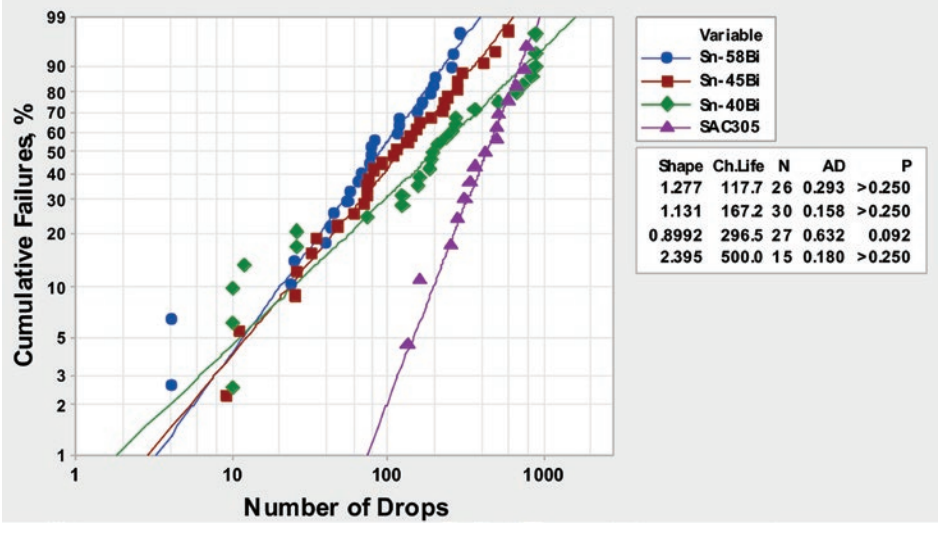

Figure 2: Weibull distribution of drop shock failures of various LTS alloys using CTBGA84.

peratures above 200°C, which would defeat the purpose of using a low-temperature alloy in lieu of SAC alloys. Besides that, reducing Bi content from 58 to 40 wt.% increases the drop shock characteristic life (i.e., 63.2% cumulative failures) in 77%, but such performance is still 40% lower than the requirement for a SAC305 drop-in replacement.

Among dozens of Sn-Bi alloys with various combinations of additives, it was found that HRL1 had the best drop shock performance for both hybrid and homogenous joints, as shown in Figure 3. The Weibull distribution plots show that HRL1 alloy/SAC305 hybrid solder joints drop shock characteristic life is 82.7% of SAC305 homogeneous solder joints in the BGA84. The LGA84 is used as a quick method to evaluate the drop shock behavior of homogeneous solder joints. In this case, HRL1 alloy drop shock characteristic life is slightly higher than SAC305. In each case, HRL1 and SAC305 Weibull curves are within the 95% confidence interval. It is also interesting to note that the shape parameter for HRL1 and SAC305 are identical for the BGA84 (1.27) and almost identical for the LGA84 (1.83 and 1.73, respectively). A plot of the respective distribution fits without plotting the symbols, as shown in Figure 3 (b), highlights the aspects discussed previously.

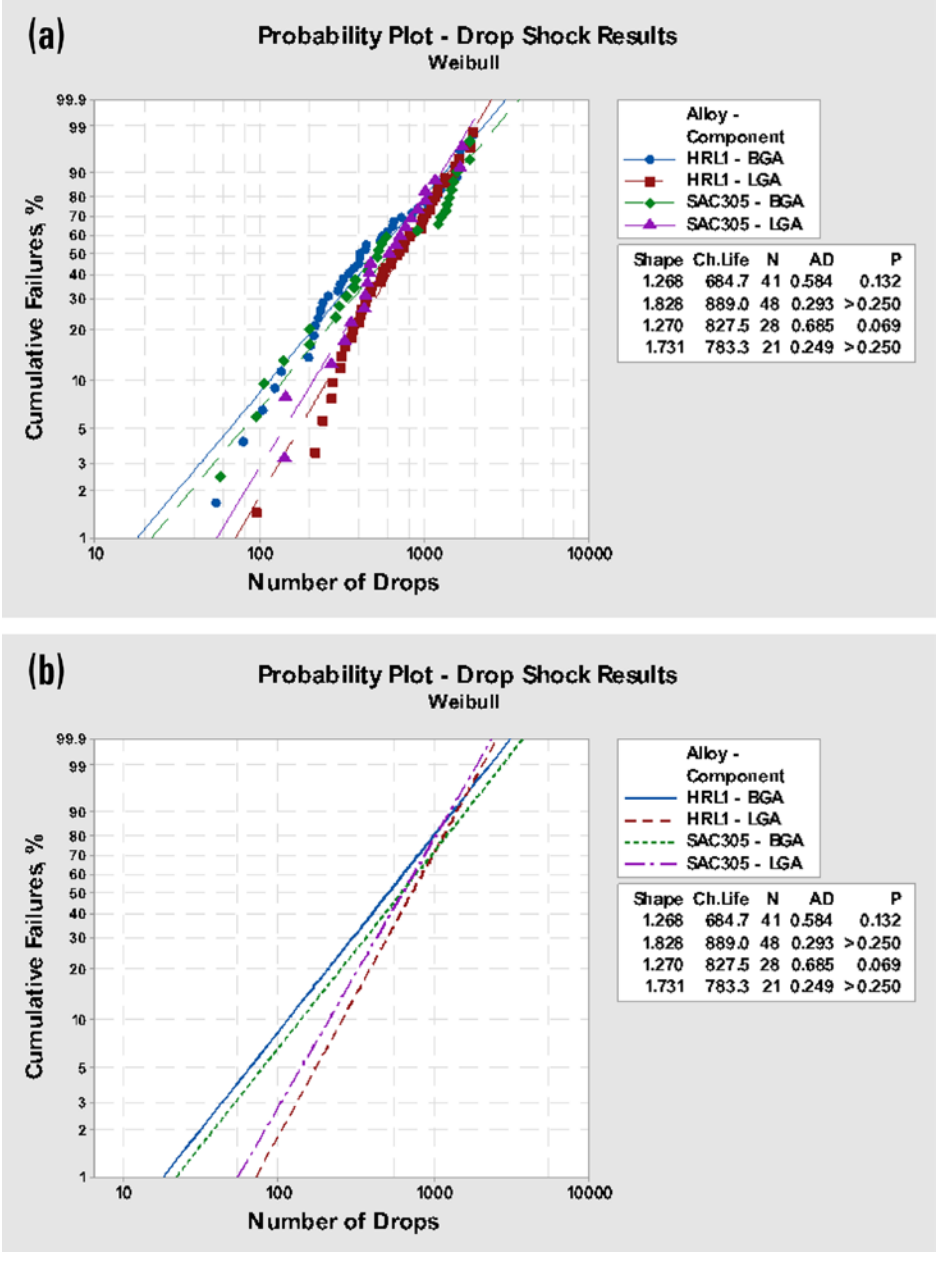

Figure 3: Probability plot of BGA84 drop shock failures. (a) Data point symbols and Weibull distribution fit and (b) Weibull distribution fit omitting symbols.

Thermal reliability tests were performed using a single zone air-air thermal shock chamber, where the samples cycled from -40 to +125°C, with 10 minutes dwell time at each temperature up to 2,000 cycles. The electrical resistance of the components was continuously monitored, and failures were defined as an increase of 20% or more in electrical resistance for five consecutive readings, as described in the IPC 9701-A standard. Figure 4 shows accumulated failures after 1,000/1,500/2,000 thermal cycles. For the in-situ monitoring, only hybrid LTS/SAC305 solder joints were considered while compared to SAC305 joints. No failures were observed in the first 1,000 cycles. After 1,500 cycles, failures

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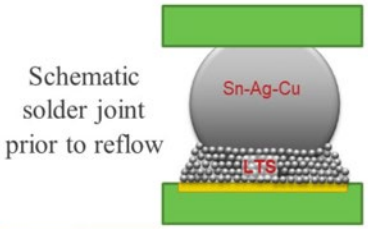

In situ monitoring of electrical resistance
Failure Criteria: IPC 9701 standard
TC Profile: -40°C (10 min) ↔ +125°C (10 min)

Alloy	% TC Failures		
	0-1000 TC	0-1500 TC	0-2000 TC
Eutectic Sn-Bi	0	7	67
HRL1	0	0	13
SAC305	0	0	11

Figure 4: Thermal cycling accumulated failures on hybrid LTS/SAC305 BGA84 solder joints.

quickly accelerated for the eutectic Sn-Bi alloy, while HRL1 closely followed SAC305 behavior until 2,000 cycles.

Solder Joint Evaluation

While in-situ monitoring of solder joint electrical resistance provides quantitative information of what happens to the solder joint during thermal cycling, the analyses of cross-sections provide visual reference of the corresponding degradation (if any) due to thermal cycling. Figure 5 shows a few examples of as-soldered hybrid HRL1/SAC305 solder joints (BGA432, BGA208, and BGA84) and HRL1 homogeneous solder joints (LGA256, MLF100, and chip resistors 1206, 0805 and 0201). For optimized assembly and reflow conditions, and considering the size of these packages, warpage or soldering defects were not observed.

Figure 6 shows the cross-sections of (a) BGA84 solder joints after 1,500 thermal cycles and (b) chip resistors 1206 after 2,500 thermal cycles. Hybrid eutectic SnBi/SAC305 solder joints show higher degradation than hybrid HRL1/SAC305 solder joints, after 1,500 cycles. Cross-sections of chip resistors 1206, from a separate thermal cycling test, show that after 2,500 cycles, HRL1 homogeneous solder joints have little degradation. Compar-

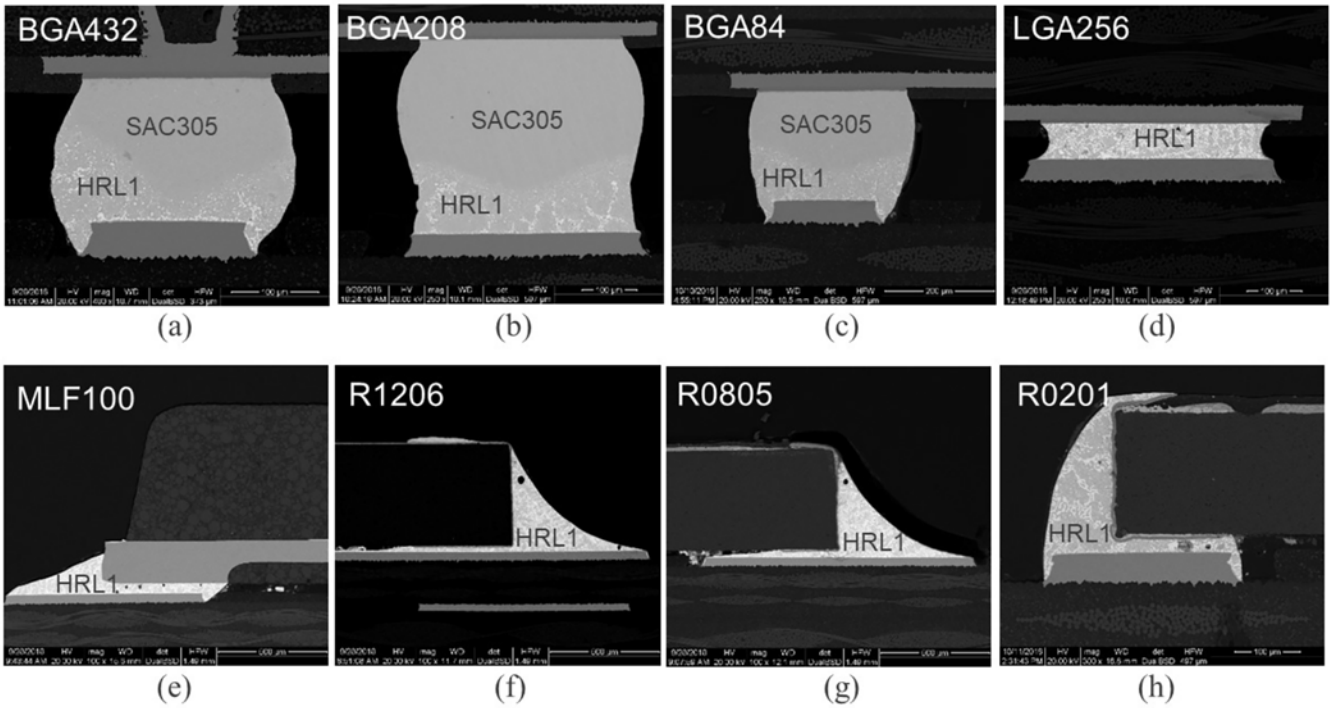

Figure 5: Examples of cross-sections showing (a-c) hybrid HRL1/SAC305 solder joints and (d-h) HRL1 homogeneous solder joints. Images taken at various magnifications, as indicated in the respective image.

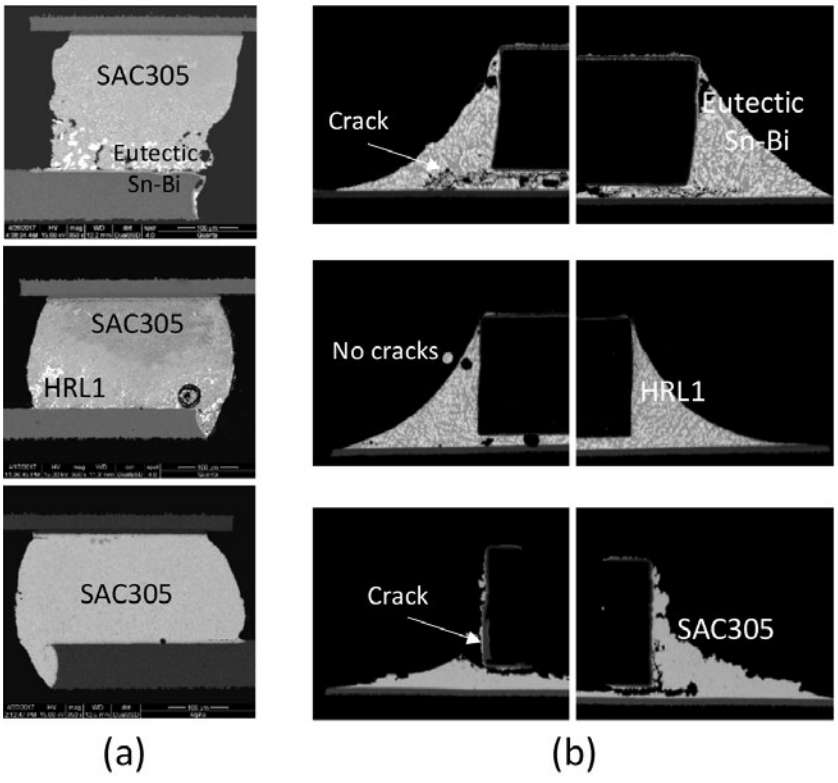

Figure 6: Cross-sections of (a) BGA84 solder joints after 1,500 thermal cycles and (b) chip resistors 1206 solder joints after 2,500 thermal cycles.

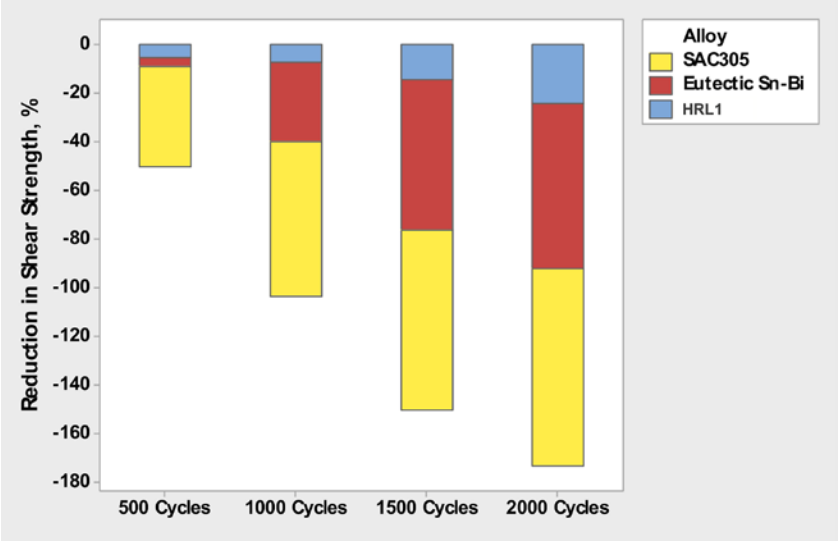

Figure 7: Effect of thermal cycling on shear strength.

atively, extensive cracks are observed in SnBi and SAC305.

For these testing conditions and components, all three alloys show a reduction in shear strength after thermal cycling (Figure 7), but HRL1 microstructure seems to withstand better the strains due to stress from thermal cycling. At 500 cycles, the shear strength of the eutectic SnBi and HRL1 has only a small decrease from their initial values of 10.6 and 11.2 kgf, respectively, whereas SAC305 loss in shear strength is eight times higher. After 2,000 cycles, HRL1 shear strength is 24% lower than its initial value, whereas the eutectic SnBi is 68.4% lower, and SAC305 is 81% lower (from its initial value of 10.1 kgf).

Summary

Given the growing demand for high-reliability, low-temperature, lead-free solder alloys that can be reflowed below 200°C, the alloy characteristics—including melting behavior, microstructure, and thermomechanical properties—need to be carefully considered. For the packages and experimental conditions discussed, the results shown here can be summarized as follows:

- HRL1 solder combines the higher tensile strength of SnBi alloys with yield strength and elongation similar to SAC305.
- HRL1 solder enables peak reflow temperatures as low as 185–190°C for assembling BGA packages with Sn-Ag-Cu balls (i.e., hybrid solder joints), or 170–175°C for homogeneous HRL1 solder joints.
- HRL1's drop shock and thermal cycling performance enables its use as a drop-in replacement for the test vehicles and experimental conditions shown here, and on a variety of other applications.

Acknowledgments

We thank our colleagues at the India R&D Centre for their key support for this work. We

are also grateful to other colleagues that participated in the discussion of the work from which this manuscript is derived. **SMT007**

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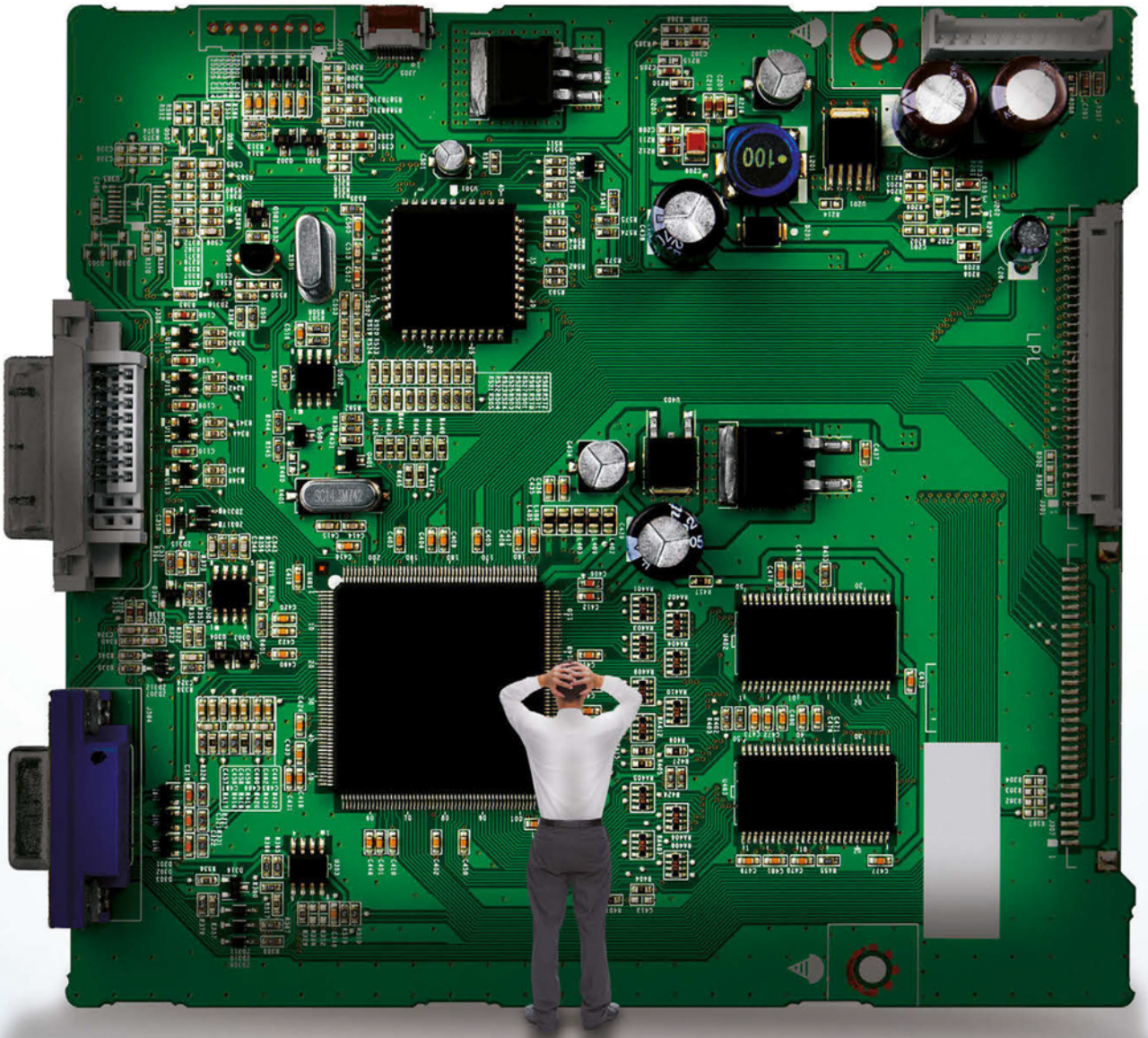

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Quest for Reliability

Feature Column by Eric Camden, FORESITE INC.

Solder is inarguably one of the required building blocks for electronic assemblies, and apart from a few exotics, every assembly in the world has it. Solder, in general, has been around for over 5,000 years, by some accounts, and used for weapons, jewelry, and stained glass, among other items. Fast forward about 4,900 years (give or take), and now it's in pretty much everything with a battery or a plug.

For the first 100 years, tin-lead solder dominated the electronics assembly process with proven results. In 2006, everything changed for the vast majority of contract manufacturers with the RoHS directive that effectively removed lead from the soldering process for all products to be built or imported into the EU. There are plenty of opinions on both sides of this issue to this day on whether this was a good idea, or even necessary. When it comes to meeting the requirement, those opinions and historical reliability data are not taken into consideration.

Now, tin-lead is used for very few assemblies, and those are almost always high-reliability applications like medical and aerospace. Directive 2002/95/EC ushered in the era of lead-free solder, as well as questions about any impact removing lead may have on solder joint quality. Removing lead increased the amount of thermal energy required to melt the solder and create a good IMC. Removing lead also increased the risk of tin whisker formation.

I talk a lot about dendrite growth, but although whiskers have the same failure mechanism as a dendrite, they don't require moisture or conductive residues. According to the NASA Goddard website, the first pub-

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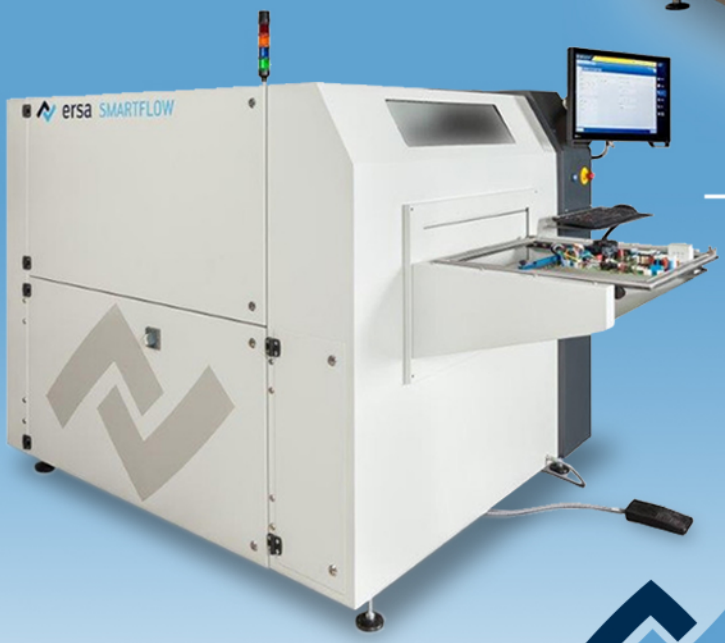

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lished reports of tin whiskers dates back to the 1940s. Since removing lead promotes tin whiskers, it was necessary to add other metals to help mitigate whisker growth, and the most popular solder on the market is SAC305 (tin/silver/copper). There are other variations of content, but pure tin solder is rarely used at this point.

A lot of research is being done to formulate a better solder regarding solder joint strength and tin whisker mitigation as part of ongoing advances in soldering. Other paste formulations are adding bismuth or zinc for lowering melting points, but those additions come with the trade-off of more risk for oxidation—particularly with zinc—so you really have to take a good look at your product's intended purpose and end-use environment to determine which formulation is best for you.

Solder itself is only one part of the overall advances in soldering; other major factors are the dispensing and inspection equipment.

Solder itself is only one part of the overall advances in soldering; other major factors are the dispensing and inspection equipment. One of the biggest advancements we have seen around here is jet-printable solder paste. This is certainly not a new technology, but as of today, we have not seen widespread adoption of jet printing, so we would consider it fairly new.

There are already a few companies using this technology, and from a reliability standpoint, we see the biggest benefit in the way it reduces bridging and/or skips from dirty stencils and excessive solder applications, which reduces the amount of flux applied. When less flux is applied, you are always better off, providing you see acceptable solder joints, of course. That is what I want to remind everyone here with this column.

You can use the latest and greatest solder and application methods, but that will never preclude them from needing to be tested for quality. As always, unless you have contracts in place that state otherwise, the best place to start will usually be IPC for guidance on how to best determine which test is applicable to your product. The basic visual inspection and acceptance criteria are found in the IPC-A-610 standard that covers all types of solder joints. The criteria found in the 610 covers parameters like end joint width, solder thickness, fillet height, etc. What it does not cover is what the IMC should look like, as that would be impossible to determine in a non-destructive manner.

Cross-section is the best tool available for determining solder joint quality. The process is covered in IPC TM-650 2.1.1. I say this is the best tool because it is really the only way to see if your assembly process is forming a solder joint that is acceptable. The old leaded or even lead-free thermal profiles may or may not be sufficient with new metallurgy regarding IMC and hole fill for PTH. Cross-section with SEM inspection is also a crucial step in qualifying any soldering process because you need to get in there and see how well the solder is wetting to the pad and look for cracks and voids and any number of other conditions that weaken the joint. This is on top of the vibration testing and thermal cycle/shock test to determine the fatigue effect on the joint.

No matter what your material choices are, or the reasons you have for making those choices, you still need to do the work to verify that those choices will yield a reliable solder joint. Without that proof, you have nothing but unanswered questions about reliability. **SMT007**

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

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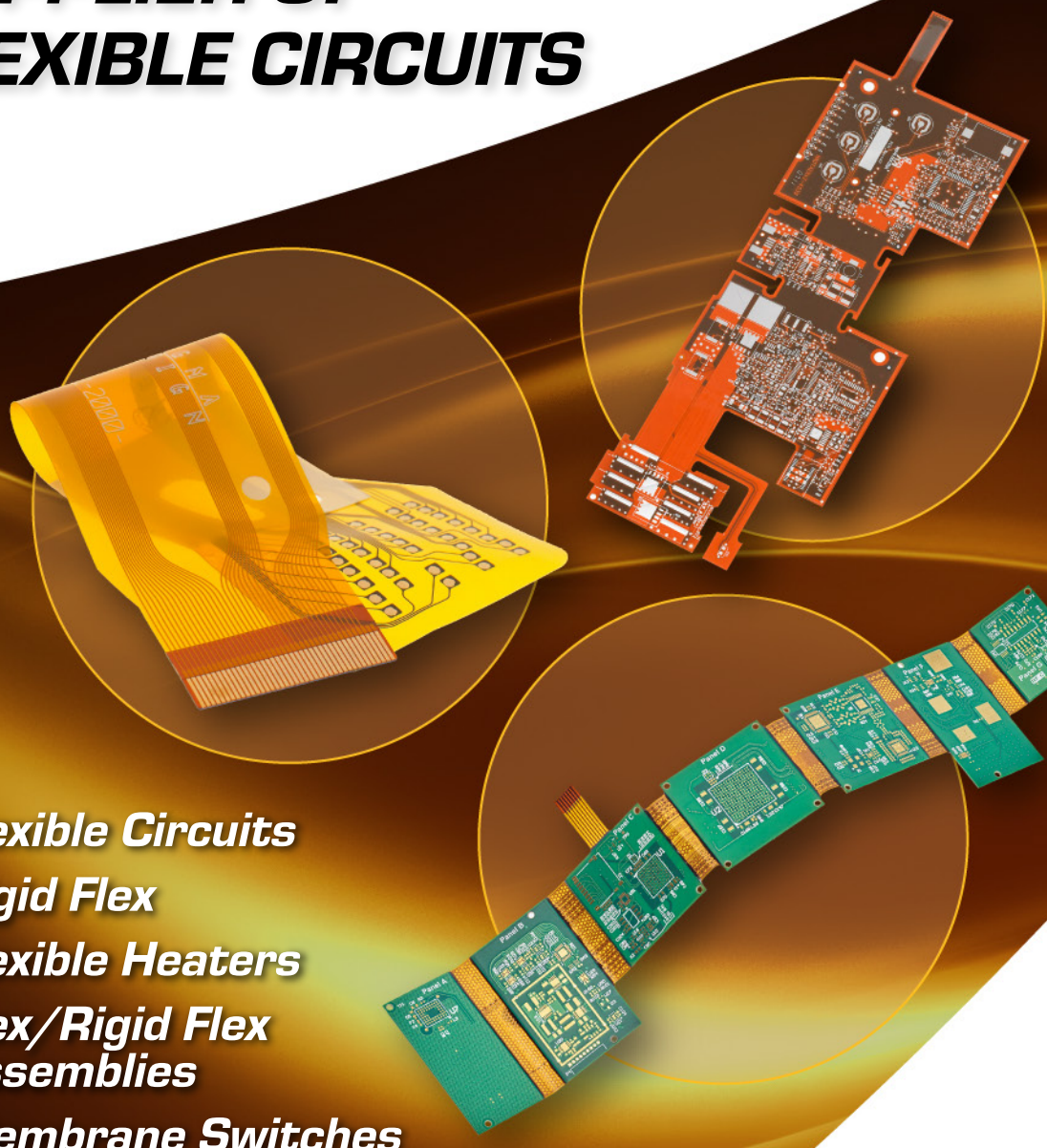

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Chrys Shea

MTV Offers Solder Paste Testing Solution

Feature Interview by Nolan Johnson
I-CONNECT007

The miniaturization test vehicle (MTV) is a common benchmark test board that can gauge about 25 different paste properties and analyze how different solder pastes will perform in an assembly line. Chrys Shea details the work she's done to develop and release the MTV.

Nolan Johnson: Chrys, let's talk about your recent work with the SMTA specifically related to the MTV.

Chrys Shea: The MTV is meant to be a test vehicle that will help qualify new packages and processes for the next at least two to three years, but hopefully longer. We can always spin it if we need to get something smaller than an 0201 metric or a 0.3-millimeter BGA on there, but it's sufficient to say that it will be solid for a while.

Johnson: What's the overall purpose of this board and this exercise?

Shea: The original purpose of it was to help people quickly and easily qualify new solder paste because there's always a lot of mystery around it and a fear of change; the process chemistry you're currently using is the devil you know versus taking a risk on the devil you don't. But every couple of years, solder paste manufacturers come out with better and better formulations. As a consultant, it kills me to go into a place where they need help and find them using a first-generation, lead-free solder paste when there are much better ones out there now. The impetus was to make qualifying a new paste quick, easy, and data-driven.

Johnson: For those who haven't met you yet, what's your background? What do you do as a consultant?

Shea: My background is in process engineering. I spent the first eight years of my career on shop floors, either in production or an NPI capacity. Over the next 12 years, I worked for suppliers, helping people on production floors and managing some solder paste R&D and testing labs, and then I struck out on my own as a consultant. Now, I work independently for users or suppliers as need be.

Johnson: And your key area of expertise?

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Shea: Soldering. I started out almost 30 years ago wave soldering. I love making solder joints. We do a lot more SMT than wave soldering these days, but I particularly enjoy stencil printing because it merges two of my favorite fields: automation and material science.

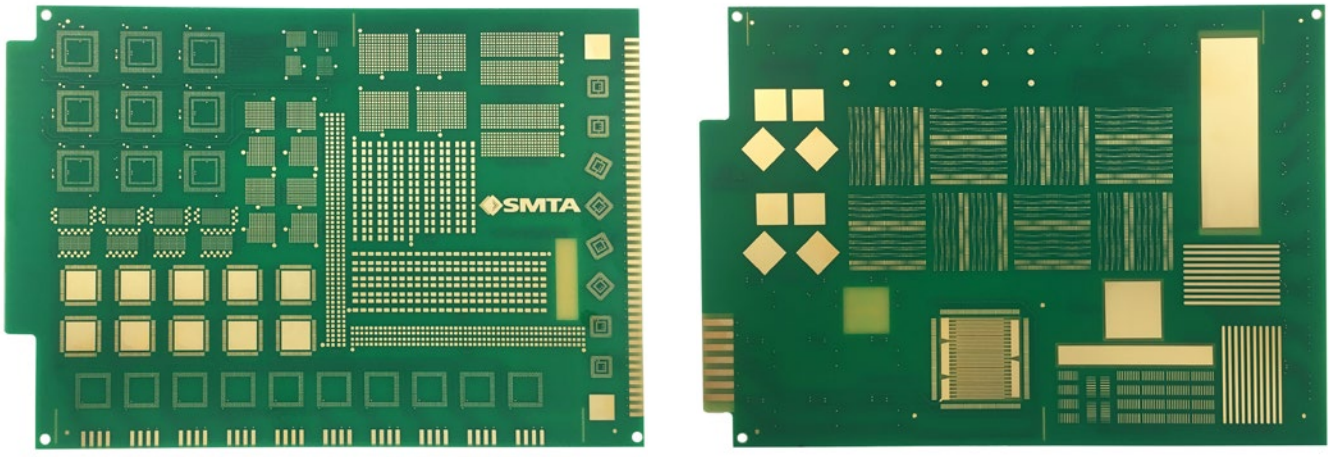
Johnson: It seems to me like a test vehicle such as this should have been around a lot earlier. How did this get started? What caused that to happen now?

Shea: What caused it to happen now is that it was an internal test vehicle with Henkel Electronic Materials, and it had a lot of good features on it, so some of their customers were requesting to use it themselves. At that point, Henkel brought me in, we did a first run of it, and we realized we needed to add some intelligence. We had a lot of empty real estate on the board so we could add more features, and we needed to reduce the cost to make it feasible for the general public. We went through that exercise.

This was my favorite project ever and probably the capstone of my career. As we respun this board and added the intelligence, more features, and the embedded DOEs, I drew on things I learned at every job I've had in the last 30 years. This was a great project for me. We introduced revision 1, and it had the Henkel logo on it, and the industry wasn't as accepting as I would've hoped. We thought, "We need to make this a test vehicle for everybody," and I can understand why other companies would not want the Henkel logo in their lab. We talked to SMTA and renamed it the SMTA board, but it is sold through Practical Components. SMTA gets a royalty for every board and kit they sell, and that money goes toward the SMTA education funds. It's a win-win all the way around.

I'm particularly interested in this because I've seen so many different test vehicles. Every large contract shop has a different test vehicle that they've done themselves, and a lot of the smaller shops don't, so they use ones that they can buy online through Practical. Nothing was really modern, and there were no common denominators between them. In other words, I could read a study by Flex and a study by Jabil, but because they're not using the same test vehicles and the same component footprints, I can't compare the data apples to apples. As we get more and more users on board with this, we'll have a lot more of good published data that we can compare.

On the supplier side, I would like to see everybody testing their solder paste on the same test vehicle using the same test method because it will make deciphering supplier data much easier and more straightforward. You might recall when we started checking placement rates with an IPC standard because every supplier had its own tests and metrics. Right now, we have no real standards for print quality that we can adhere to. Everybody tests and publishes their own data on the honor system.



The Miniaturization Test Vehicle board, top and bottom.

Enter number of boards to populate in each of 10 print runs: 3

Kit Configurator for Miniaturization Test Board

Comp Type	Pitch	I/O	Body Size	Type	Qty per board	# paste deposits/print	# of components	Unit	Cost Each	Cost/board	Reflow Qty	Set up Qty	# Components or Reels	Kit Cost	Practical Item #	Practical Components Description/ Component Name in ODB++ BOM
BGA/LGA	0.3mm	368	8mm	ChipArray - Very Thin	8	2944	24	Tray	$ 8.95	$ 71.60	3	12	36	$ 330.20	31610	A-CVBGA368-.3MM-8MM-DC-LF-305
	0.4mm	620	14mm	Thru Mold Via PoP	9	5580	27	Tray	$ 12.75	$ 114.75	3	12	39	$ 505.25	31558	A-TMV620-.4mm-14mm-DC-LF-125
	0.5mm	228	12mm	ChipArray - Very Thin	10	2280	30	Tray	$ 4.50	$ 45.00	3	12	42	$ 197.00	31329	A-CTBGA228-.5mm-12mm-DC-LF-305
MLF/ QFN	0.4mm	100	12mm	Single Row MLF	10	1000	30	Tray	$ 2.90	$ 29.00	3	12	42	$ 129.80	32202	A-MLF100-12mm-.4mm-DC-Sn-T
Discretes For overall defect rate, use capacitors For solderball analysis use resistors	1206	2		0 Ohm Resistor	50	100	150	T&R	$ 0.010	$ 0.50	3	reel	1	$ 50.00	16047	1206SMR-PA-5K-Sn-0
	1206	2		Capacitor	50	100	150	T&R	$ 0.030	$ 1.50	3	reel	1	$ 120.00	16604	1206SMC-PL-4K-LF
	0603	2		0 Ohm Resistor	50	100	150	T&R	$ 0.010	$ 0.50	3	reel	1	$ 50.00	16070	0603-SMR-PA-5K-Sn-0
	0603	2		Capacitor	50	100	150	T&R	$ 0.000	$ 0.02	3	reel	1	$ 16.00	16602	0603SMC-PA-4K-LF
	0402	2		0 Ohm Resistor	400	800	1200	T&R	$ 0.010	$ 4.00	3	reel	1	$ 100.00	16069	0402SMR-PA-10K-Sn-0
	0402	2		Capacitor	400	800	1200	T&R	$ 0.004	$ 1.60	3	reel	1	$ 40.00	16601	0402SMC-PA-10K-LF
	0201	2		0 Ohm Resistor	400	800	1200	T&R	$ 0.010	$ 4.00	3	reel	1	$ 150.00	19865	0201SMR-PA-15K-Sn-0-P
	0201	2		Capacitor	400	800	1200	T&R	$ 0.008	$ 3.20	3	reel	1	$ 120.00	11710	0201SMC-PA-15K-LF-M
	01005	2		0 Ohm Resistor	400	800	1200	T&R	$ 0.100	$ 40.00	3	reel	1	$ 500.00	19921	01005SMR-PA-TRB-LF-0
	01005	2		Capacitor	400	800	1200	T&R	$ 0.100	$ 40.00	3	reel	1	$ 500.00	19481	01005SMC-PL-TRB-LF
	008004	2		*Resistor is not available at this time*												
	008004	2		Capacitor	400	800	1200	T&R	$ 0.400	$ 160.00	3	reel	1200	$2,000.00	19220	008004SMC-5K-LF
				Total Paste Deposits per board		**17804**				**$ 515.67**			***Kit Cost with 008004***	**$4,808.25**	***per run***	
				Total Solder Joints per run		**53412**							***Kit Cost w/o 008004***	**$2,808.25**	***per run***	
				Total Opportunities per run		**62524**							* Reels of 01005s are $500 for 5K parts Reels of 008004s are $2,000 for 5K parts			
													Kit excl 01005 and 008004	**$1,808.25**	***per run***	
													Board excl 01005 and 008004	**$ 275.67**	***per board***	

Bill of materials cost and sample size calculator.

Johnson: That makes a common benchmark test board all that more important.

Shea: Exactly. We're running so much leaner. As we recover from the pandemic, we're going to have a lot of catch up to do. We don't have a lot of time to wait.

Johnson: Walk me through how the board gets used then in the field.

Shea: Typically, if you were using this to evaluate a solder paste, you would take this board to run the top side and the bottom side, and we have nested some DOEs in there. The user does 10 prints top side, and populates three of the boards, and then sets that stencil aside and run the bottom side. While the top side stencil and paste are doing an idle time, the user prints five boards on the bottom side and then shears the solder paste on the bottom side for a couple of hours to mimic a regular stencil life test and how it would perform on the assembly line before printing five more. The user reflows some boards, reinstalls the top side stencil, and then runs 10 boards again, to see the impact of idle time on printability.

There's a flow chart you can follow. There's also a step-by-step Excel spreadsheet you can follow that tells you within 30 prints and only five hours of assembly line time, you're going to be able to gauge about 25 different paste properties and how they affect your line—not some lab's line, but your assembly line with your heat and humidity levels with your typical placement forces and reflow profiles. That's a lot different from what we see in the lab. The delta from the lab to the line is huge in PCB assembly. That's why we like to test on the line, but we have to make it fast and economical. What used to take two weeks can now be done in about five hours if you use the test vehicle and follow the step-by-step instructions.

Johnson: Am I right to assume, then, that when I order up the test board, there's a packet of 30 test boards and maybe even some components?

Shea: I created a simple spreadsheet so that the users can look at the sample size and costs and determine what's best for them. Then they order directly from Practical. When we first decided to commercialize the board, we decided Practical would be the ones to take care of all the supply chain and order fulfillment. Shea Engineering and Henkel are out of the picture on that now; it's strictly

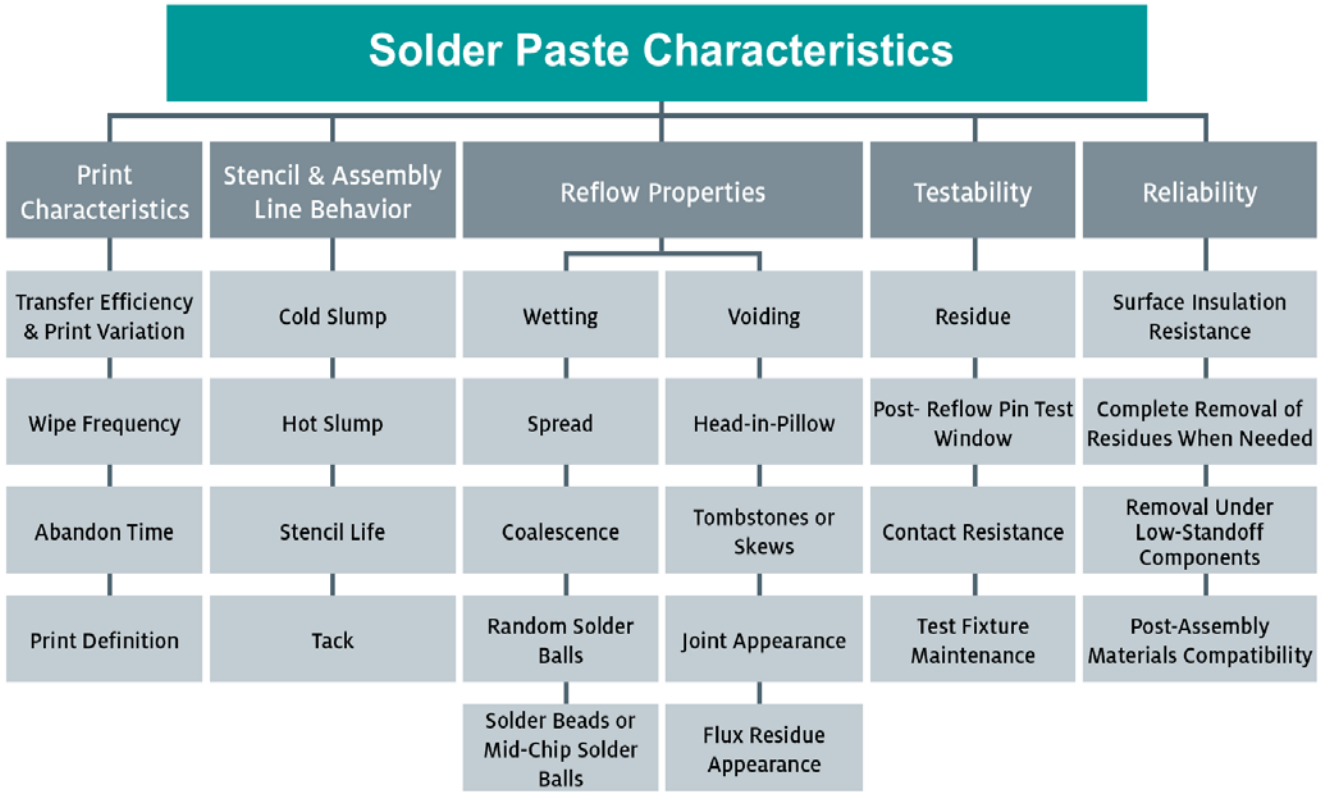
Practical Components. They order and stock the components, and every component has a part number from Practical Components to make it easy to order. Also, it has the description, so if you have some oxidized 0201s on the shelf and you'd rather use those than the bright shiny new solderable ones from Practical, you can do that. I suggest that in a lot of cases.

You can determine how much you want to order from Practical, and they'll walk you through the order, and they have all the supporting documentation that they will email to you as well, which is the bill of materials and the step-by-step instructions. There are four or five pieces there that they email out in the package.

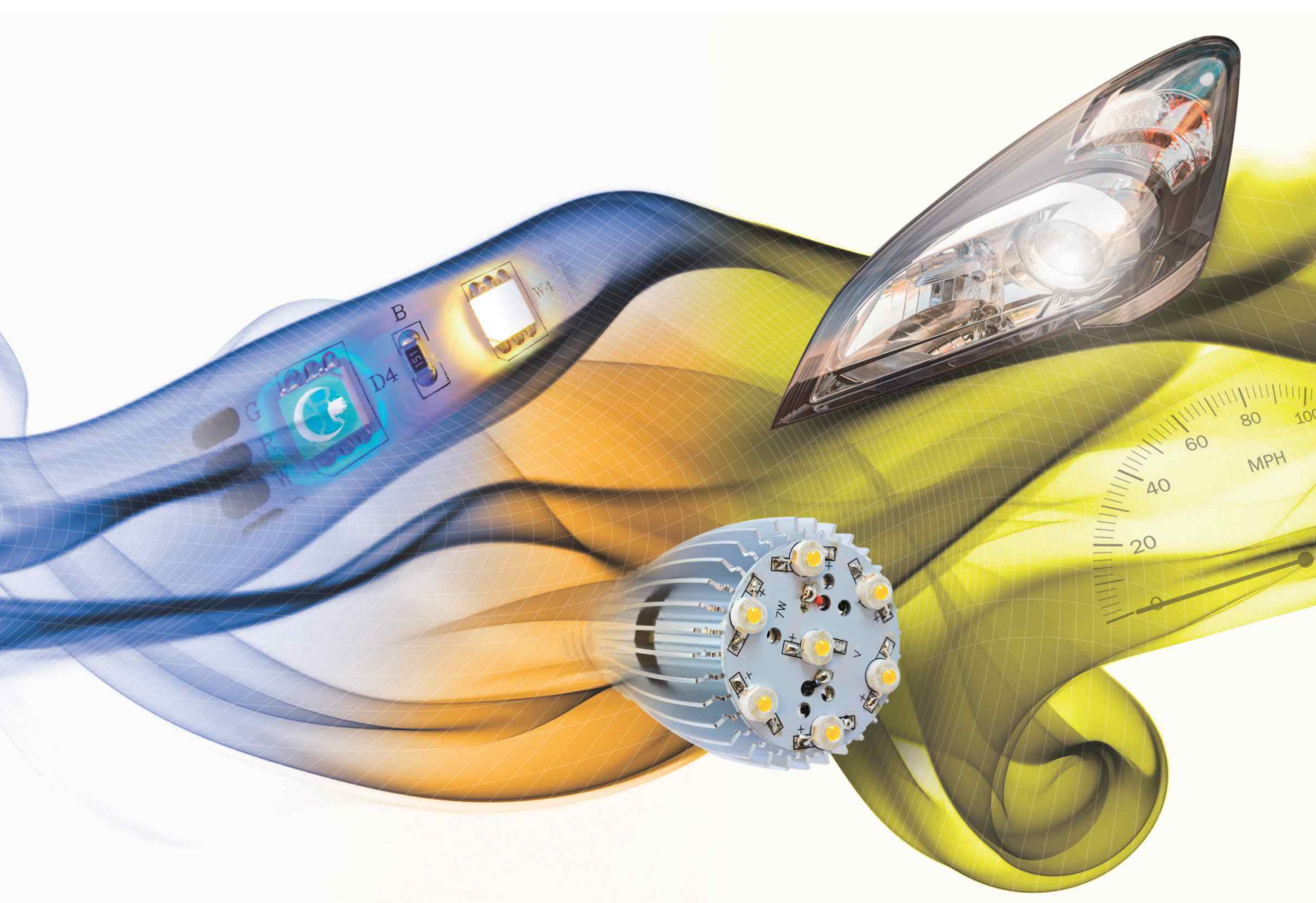
Johnson: Who should someone contact to start the process?

Shea: Contact Practical Components. They should send you a documentation package. What is in that package right now is a list of all the different tests and descriptions, the 25 different tests that are embedded in here, the bill of materials, a sample size calculator, the area ratios and reference designators, the step-by-step solder paste test process, and the scorecard. We haven't talked about scorecards yet, but that is where you rank paste performance relative to each other and look at each category of reflow, print, testability, supplier value, etc., and determine which paste gives you the best results. When some are categorized, you can say, "I'm going to trade off some reflow properties for better printing and a little response to idle time for better voiding." You can see that all on the scorecard.

Johnson: There certainly seems to be an increased specialization with respect to what the solder pastes do—what they're strong in, and what they're weak in. It's not a "one paste fits all" industry any longer. Does this test vehicle enable an assembler to characterize their line on all the different pastes they may plan to use or the various process windows, or is there



An overview of solder paste characteristics.



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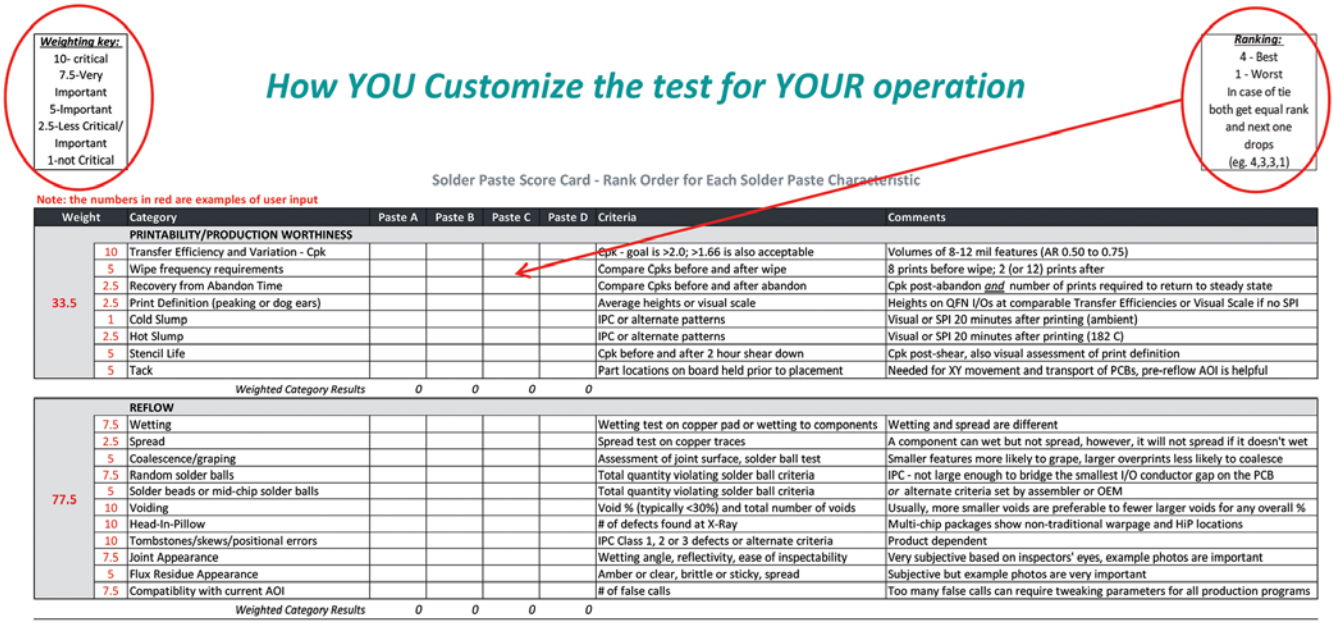
enough overlap that you generally get a good idea with one baseline?

Shea: I usually advise my clients to contact as many paste suppliers as they want, but then do a down-select to three before they run any final tests. When a user fills in the scorecard, before they put any data in it, they weight how important a particular characteristic is to their operation. Again, there are 20+ characteristics. They know what's important to them. For example, If they are a low-volume shop, response to idle time is very important to them. If they are a high-volume shop that runs 24/7, idle time is of far less consequence. Once they have determined their needs by heavily weighting their key factors, they can then effectively communicate those needs to the paste suppliers, who better understand the trade-offs in properties and can deliver the best candidate for the application.

I suggest the user choose whatever the most stringent test is and use that for a down-select. If they want to be able to run that first print after an hour, or everything they run goes through pin test, it's easy to do a down-select there. Then, they take the top two or three and run them against the incumbent. The user ranks the results in the scorecard, which multiplies the rankings by the weights to calculate the individual scores. The user can then see how each paste compares to the incumbent in each characteristic and category. They make an informed, data-driven decision, and as they migrate toward their new soldering chemistry, they are guarded against the gotchas because they've already looked at 25 different properties on their assembly line and have a good idea of what to expect.

We've run into situations where somebody selects the paste because it's low on voiding, and they find out it's not very active, and it doesn't wet very well, or it has great response to idle but isn't pin-test friendly. There's always a trade-off in solder paste. This test method is meant to encompass all the different properties, so the user knows what their trade-offs are right up front before implementing it.

Johnson: An evaluating assembly shop is going to get some answers on if I can achieve the kinds of precision that I want and where my current set-up is failing. Is it the paste or equipment I'm using or the expertise of my operators? It would seem that this will tend to shake out the problem areas for the assemblers.



Weight		Category	Paste A	Paste B	Paste C	Paste D	Criteria	Comments
		PRINTABILITY/PRODUCTION WORTHINESS						
	10	Transfer Efficiency and Variation - Cpk					Cpk - goal is >2.0; >1.66 is also acceptable	Volumes of 8-12 mil features (AR 0.50 to 0.75)
	5	Wipe frequency requirements					Compare Cpks before and after wipe	8 prints before wipe; 2 (or 12) prints after
	2.5	Recovery from Abandon Time					Compare Cpks before and after abandon	Cpk post-abandon *and* number of prints required to return to steady state
33.5	2.5	Print Definition (peaking or dog ears)					Average heights or visual scale	Heights on QFN I/Os at comparable Transfer Efficiencies or Visual Scale if no SPI
	1	Cold Slump					IPC or alternate patterns	Visual or SPI 20 minutes after printing (ambient)
	2.5	Hot Slump					IPC or alternate patterns	Visual or SPI 20 minutes after printing (182 C)
	5	Stencil Life					Cpk before and after 2 hour shear down	Cpk post-shear, also visual assessment of print definition
	5	Tack					Part locations on board held prior to placement	Needed for XY movement and transport of PCBs, pre-reflow AOI is helpful
		Weighted Category Results	*0*	*0*	*0*	*0*		
		REFLOW						
	7.5	Wetting					Wetting test on copper pad or wetting to components	Wetting and spread are different
	2.5	Spread					Spread test on copper traces	A component can wet but not spread, however, it will not spread if it doesn't wet
	5	Coalescence/graping					Assessment of joint surface, solder ball test	Smaller features more likely to grape, larger overprints less likely to coalesce
	7.5	Random solder balls					Total quantity violating solder ball criteria	IPC - not large enough to bridge the smallest I/O conductor gap on the PCB
77.5	5	Solder beads or mid-chip solder balls					Total quantity violating solder ball criteria	*or* alternate criteria set by assembler or OEM
	10	Voiding					Void % (typically <30%) and total number of voids	Usually, more smaller voids are preferable to fewer larger voids for any overall %
	10	Head-In-Pillow					# of defects found at X-Ray	Multi-chip packages show non-traditional warpage and HiP locations
	10	Tombstones/skews/positional errors					IPC Class 1, 2 or 3 defects or alternate criteria	Product dependent
	7.5	Joint Appearance					Wetting angle, reflectivity, ease of inspectability	Very subjective based on inspectors' eyes, example photos are important
	5	Flux Residue Appearance					Amber or clear, brittle or sticky, spread	Subjective but example photos are very important
	7.5	Compatiblity with current AOI					# of false calls	Too many false calls can require tweaking parameters for all production programs
		Weighted Category Results	*0*	*0*	*0*	*0*		

A scorecard breakdown.

Shea: Exactly. If they don't like the reflow results on any of the pastes, maybe they need to go back and revisit their profile. I see this phenomenon all the time, where people use banged up stencils and squeegees. If you go into a test introducing that much noise into it, you're not going to get very clear results, and I tend to get on a soapbox about tooling because it's so important. There's a lot of different things to consider, but you're absolutely right. You will find your own factory's strengths and weaknesses.

A lot of my clients test the most popular pastes in the country. I've run so many tests on them that by looking at the data off of somebody's printer or SPI machine, I can tell you whether a particular paste should print that way or not. And using the same test board makes that call even easier.

Johnson: To run this benchmark test, do you need somebody that knows the test well to help you interpret the data?

Shea: I would say no because we tried to make it as easy as possible. This was an effort by myself, Dr. Neil Poole of Henkel—who has over 30 years in being on the floor printing at various different customers—Dr. Mark Currie—who has 25–30 years in paste development and did his Ph.D. in solder paste printing—and Doug Dixon—who is also a 30–35-year veteran of the industry. There were well over 100 years of experience trying to make this simple as possible, and that's where the step by step comes in. That's also where the list of tests and descriptions comes in. This should be completely self-manageable; several organizations have run it according to this, and they've done absolutely fine with it. You don't need an expert. That said, I'd be happy to help you for a certain fee (laughs), but you can do this all on your own.

Johnson: What else can we use this board for?

Shea: Many people need to demonstrate capability for the next package size down, which for a lot of us is 01005, and there's 800 components or 1600 pads on the board. There's also 0.4- and 0.3-millimeter devices on the board, as well as 0.4-millimeter BGAs. A lot of assemblers, especially the contract shops, need to show the capability to their OEM before they can start production on these new package types. This demonstrates the assembly process.

Also, because the board is wired out to test points or gold fingers, you can perform reliability qualifications on these new package types as well. We have also used it on multiple occasions to test different stencil designs. And we've been using it a lot to develop the print process for the 008004s or 0201 metrics in conjunction with a stencil printer manufacturer and a paste manufacturer. We're all working together to roll out a process for that.

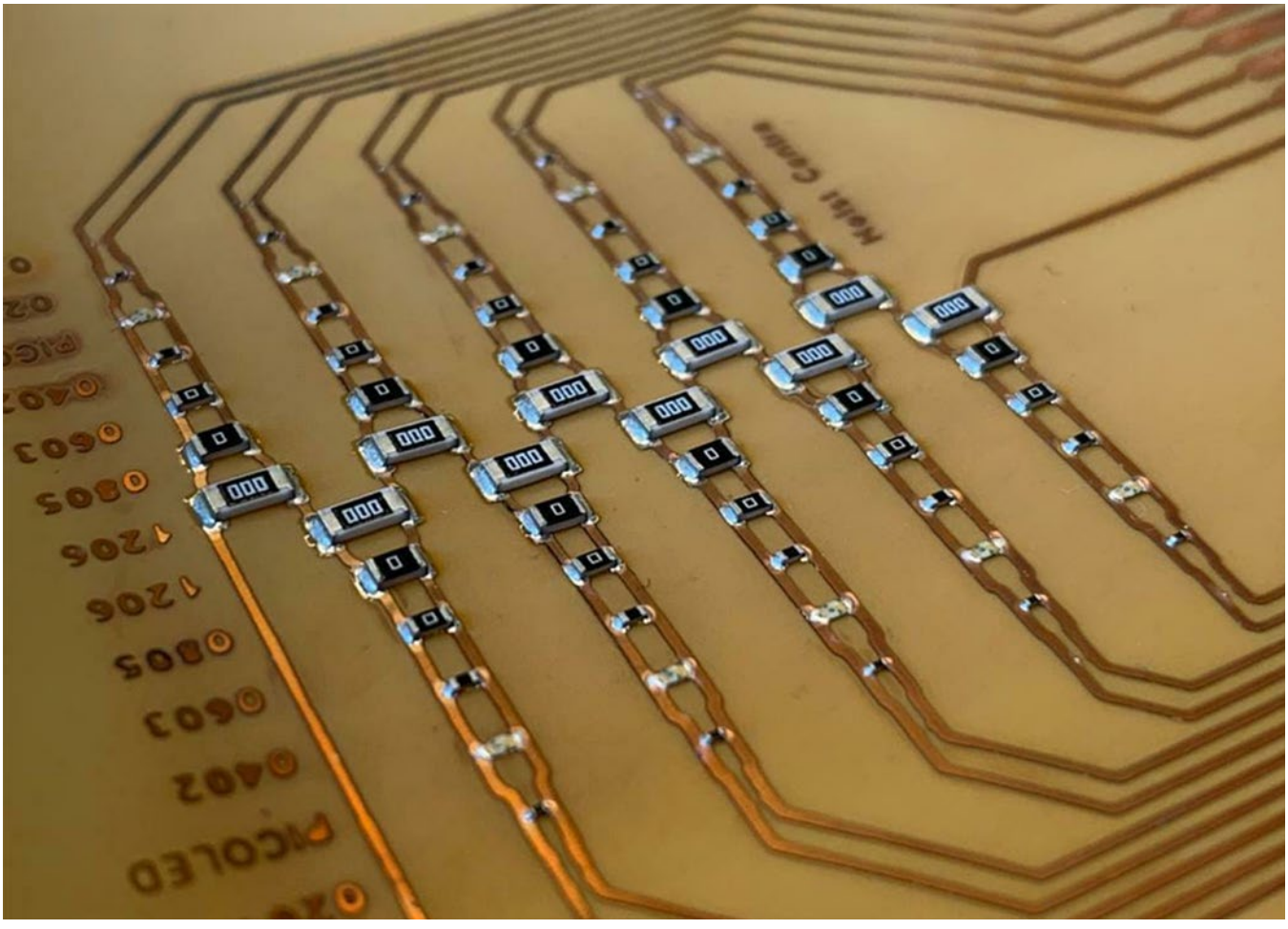
One of the pieces of feedback I got was from an OEM who said, "Given this kit, I should be able to walk into any CEM at 8:00 in the morning with a box of parts and a jump drive of files, and if they're not running by noon, they're not any good." We're using it to benchmark SPI and AOI equipment. Also, we have IPC placement rates and other placement rates. I'm aware of at least one company that's taking this board to the different placement manufacturers to see how close their placement rates are to published data and what's going to be the best for their operation.

Johnson: It sounds like there is plenty of opportunity for this board to be used as a testbed.

Shea: Yes, for all kinds of things. Hopefully, it will become a more mainstream universal test vehicle for the next few years. And when we need to put a smaller component on, I'll be happy to spin the artwork. That's what makes it fun.

Johnson: Fantastic. Chrys, thank you for your time.

Shea: It's my pleasure. SMT007



NovaCentrix Offers Photonic Soldering Solution

Feature Interview by the I-Connect007 Editorial Team

The I-Connect007 editorial team spoke with Stan Farnsworth and Dr. Rudy Ghosh of NovaCentrix about their photonic soldering solution, a process they adopted from their photonic curing tools. The nascent technology has the possibility to be disruptive as it potentially offers quicker speeds better suited for high volume and uses less energy in heating.

Barry Matties: Can you give us a brief overview of your background and technology?

Stan Farnsworth: I'm the chief marketing officer and one of the founding members going back to 1999 for the predecessor company. We've been focused on printed electronics for close to 15 years now, starting with electrically conductive inks as an implementation of the nanomaterials and nanoparticles that the company was formed to produce.

As we got involved in electrically conductive inks, we realized that, for the industry to move forward, there needed to be a way to develop, dry and center those inks into a useful, conductive product for low cost, but also flexible, substrates. It involves different kinds of plastic polymers, textiles, and even paper. It's very much a departure from the traditional FR-4 kind of electronics materials that are traditionally used in the industry.

Dan Feinberg: We see some pretty significant changes in soldering. We went from hand sol-

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Stan Farnsworth

dering to wave soldering, which took a decade or so. Then, we went from wave soldering to surface mount. While that was a slow transition, it seems to have sped up. The mindset with regard to the industry now being open to change in soldering is something that will greatly accelerate the acceptance of photonic curing and soldering.

Stan Farnsworth: We realized that we could take the equipment that we use to make the nanomaterials and pivot that technology into a new product. That is our photonic curing product under the Pulseforge® brand. Those tools use flashes of broad-spectrum light energy from near IR down to UV.

Dr. Rudy Ghosh is with us today as well. He's the technical program lead for soldering. He is one of the senior members on our applications team and is leading the charge with developing the technology of the soldering. Working with some of our partners, we realized that the photonic curing tools could be used for soldering. Over the last couple of years, we got to the point where the tools could deliver the right kind of energy profile for soldering. We've been working very closely with our partners at the Holst Center in the Netherlands. They need to be mentioned as being the early developer.

Dr. Rudy Ghosh: One of the biggest challenges that are our technology partners and customers have faced is connecting these components to the substrate. Working with partners, we have realized that—for a lot of these things—the solutions pretty much have to come from us. That's why we have worked with our technology partners to make photonic soldering a key solution and even further make printed electronics ubiquitous.

Farnsworth: We sell to R&D, and we sell a different, related platform for production. It's probably not a big surprise that most of the production implementations have been in Asia. We see more R&D tool sales in Asia as well. But for some time, the R&D tool sales were primarily in the United States and Europe with occasional production tool sales. Asia is where most of the production tools are located.

Ghosh: It might be a good point to separate out photonic curing versus photonic soldering. They are both light-matter interactions. However, the timescales and energy densities that are required are very different.

Matties: How would you describe that trend? Where does it cross over?

Farnsworth: We began floating the idea of this to folks that we were working with. We then started talking about it at some of the printed and flexible electronics conferences, maybe as much as two years ago, to see if there would be any kind of reception to this. We found a lot of interest. That was an important part of our market.

We encountered two or three major opportunities in consumer electronics and medical devices that had relatively near-term product launch dates they were trying to hit. They were having some challenges engineering the solutions that their marketing teams felt were needed. We weren't far enough along to be

able to satisfy that need yet, but that was a strong indicator we were going in the right direction.

Matties: What are the key drivers behind this technology in terms of benefits?

Ghosh: If you think about some of the thermally unstable substrates—such as polycarbonate, which is used for thermoforming—these go in cars. In the automotive industry, the requirements for electronics are much more stringent than they would be for a normal consumer electronics product. When we're talking about automotive, this is mostly driven by companies with new form factors and new places where electronics can be put.

If you think about speed, a complementary technology to us is laser soldering. Nearly everything that can be done by photonic soldering can be done by laser soldering. There's no denying that. The speed, though, is three orders of magnitude slower—especially as electronics get smaller and as more and more components go on a panel. If you're going terminal by terminal, either you need dozens of lasers working at the same time—which drives the cost up—or you're proceeding slowly—which reduces your units per hour and drives the cost up. Photonic delivers a broad window of light, and anything that needs to get hot gets hot.

Matties: Would this be better suited than laser for a high-volume production environment?

Ghosh: Absolutely. Especially if you have a huge panel of micro LEDs on PAT that goes on a billboard that is 48 feet by 96 feet, for instance. The number of LEDs is enormous. You're not going to be able to do that fast with lasers, no matter how many lasers you use. Our tools are designed to be modular, delivering wide panel-sized amounts of light at a time. That's an advantage we have over lasers.

Second, if you want to move from one component to another, moving parts are involved—a level of complexity that's not ideal for production. The third part is, the soldering technology that we are talking about is pretty much an on/off technology. Whenever the light is on, things get hot. Whenever the light is off, things do not.

Dr. Rudy Ghosh

The speed is obviously the advantage, but there's also the benefit of saving on huge amounts of energy. You're heating up only what you need to heat up, which might only be a few centimeters in an area. As the industry moves toward higher speed, a completely new form factor, and the push toward green, energy-efficient factories, the technology we have developed so far is a huge winner.

Happy Holden: When I think of soldering, I think of lead-free solders or tin-lead solders or bismuth solder. When you say photonic soldering, like lasers, does this use the standard lead-free SAC305?

Ghosh: Yes.

Holden: Is the solder put down in conventional thicknesses by screening, or is this a special solder that's a nanoparticle that you guys developed?

Ghosh: All of our work so far has been done with conventional off-the-shelf solders. We have done SAC305—anything from Type 3 to Type 7. We have done single solder balls and tin-bismuth in a wide variety of sizes. We want this to be as widely available as possible to customers.

It takes years for companies to qualify a solder type and the supplier. We have gone to our initial customers and told them, "Give us the solder that you have, and we will use that." We are working with technology partners developing specific solders for a variety of applications. Our technology partners have been very impressed with how well this technology works with conventional solders, plus with solders that are being specifically designed for laser soldering or some other technologies as well.

Feinberg: What if the light were only able to hit the solder at the very top? Let's say that the solder joint was down in a cavity created by solder mask. Can the eutectic point still be reached throughout the solder joint?

Ghosh: We are using a white light source, so it depends on the size of the cavity. Nothing's beating physics. There's going to be shadowing, etc. However, if a few microns or larger, then yes, it will go into that cavity, and it will heat up the solder. Again, this is a light initiated process, but this is a thermally driven process.

Feinberg: It's thermal; it's not a photoreaction.

Ghosh: Correct. The light is only to bring in the energy. That light gets absorbed, scattered, etc., and then turns to heat, and that is driving the whole process. That's why we can use completely conventional solders. The solders are still using the same energy.

Holden: When you consider how much energy goes into an infrared reflow oven, the photonic method can't be requiring the same total energy. You're not heating the substrate. This is more a surface phenomenon.

Ghosh: Exactly. IR heaters are designed specifically to be absorbed by polymers, solvents, and organics. That's how they are designed. That's why they work so well for drying applications. You cannot keep a PET substrate under most IR heaters because the PET is again designed to absorb in the IR area. Ours is white light. We do have some IR component, but it's significantly less compared to the visual part because it's a broadband light source, we also can filter out different spectrums of light if needed. You can cut out the UV, the visible, and the IR. That allows us a level of selectivity.

Holden: Would it be akin to the energy of condensation soldering where the heat is only applied to the surface of the solder—not the entire one?

Ghosh: The amount of energy that is absorbed and converted for the reflow process. The amount of energy that the whole thing is exposed to is not because the other parts of the substrate are still seeing this energy. It's letting it pass through. In our design, we use something called a "beam dump." The energy that we're delivering needs to go somewhere. A lot of that energy that is being delivered gets dissipated.

Keep in mind that this is pulsed white light. The pulsing is very important here. If you're going to put in the same amount of heat without the heat being lost, you are cultivating too much energy, and you are going to destroy everything. Even with PET, there are two things: first, the light has been converted to heat, and second, that heat is now trying to find the best thermal pathways. One of the pathways it sees is to go through the solder and make it reflow. We are bringing in light and it is converted to heat, but then it's all about the substrate, component, solder, and conductive pathways. The substrate can be paper, fabric, or TPU.

Holden: I'm a big believer in the future of printed electronics, especially for disposable medical electronics.

Ghosh: That has been one of the main drivers for this technology: making disposable systems

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Feinberg: Is the heat generated only on the conductor, not on the dielectric?

Ghosh: Heat is generated in anything that is absorbing. You can make a dielectric that is dark in color that will absorb and get hot. But, in most cases, your dielectric layer is clear and doesn't get hot.

Feinberg: If you have a photocurable coating like a solder mask, does this add to the cure of the solder mask? In other words, would there be any thermal change to the solder mask except the immediate solder mask that is right next to the conductor?

Ghosh: It shouldn't because, first of all, if the solder mask is of a specific color—such as green—if you think about the visible spectrum, yellowish-green is pretty much the predominant color in the visual spectrum. It's mostly going to reflect that light back directly. The only light that it's going to absorb is the UV part, which was what is used to run the photoactivation. Those photoactivation steps are usually self-limiting. Once it's done, it does not continue further. Again, if you make that solder mask black, then it becomes a problem, and then we would have to most likely put a mask on top of that. But if it's in those areas where it normally has the yellow screen, it's great because it's going to reflect most of that spectrum anyway.

Holden: When do you sinter instead of solder?

Ghosh: The first step would be to sinter after you put the conductive tracks. You sinter that, make them dry, and make them conductive compared to bulk metal. Then, you stencil the solder, you pick and place the components, and then do the reflow. They are two different steps with different timescales and energy requirements. If I bring in the same amount of energy on a wet ink as I would for the solder, it is going to completely destroy the metal. The amount of solvent that's in a conductive ink would cause it to explode violently, and your tracks would not exist anymore.

But the ability to take it the liquidus temperature and then ramp it up much higher than that temperature over less than a second and drop it quickly allows us to have these intermetallic formations that are thin and continuous. Also, the cooling down process is in the seconds. When you turn the light off, there's no energy left behind. That allows us to have this nice, granular microstructure that makes the solder joints very strong.

Holden: We have an enormous problem with conventional lead-free soldering for very expensive military and high-reliability products in that holding a temperature at 230–260°C for the amount of time necessary for reflow has been breaking the microvia joints. Photonic soldering doesn't heat the substrate to anywhere near those temperatures. We're talking about some of the most expensive electronics in the world, and if there's an alternative method of soldering that does the solder of lead-free but doesn't heat the substrate, that's an enormous advantage that nobody else has.

Ghosh: Absolutely. The big advantage is that we are bringing enough energy for the solder reflow, but not enough energy to heat up bulk material. Some of our tools heat up thick metal, which is mind-blowing, but that's a different regime. That is a very specific application that could see the advantage of this. This process is self-limiting: once it becomes this nice solder joint, now it has a good thermal pathway, and it does not get much hotter. It does not give out heat to everything else that is not metal around it. It's trying to find as many metal tracks to go around and get that to even temperature.

Matties: With respect to what Happy is talking about regarding quality improvement, have you done any laboratory testing to talk about the quality and structural difference?

Ghosh: For the solder joints, we have. For it to be trustworthy, we needed to go to a third party, so that's what we have been doing recently. What we have heard has been encouraging so far.

Matties: Are you marketing your findings to OEMs?

Farnsworth: I expected there would be one particular segment that was more interested or less interested, but we've had a nice reception from all stages in the process.

With photonic curing, it's been similar. In some cases, the adoption was driven by the product designers who drove this requirement into their supply chain, requiring them to work with us to produce the new products. We've had other implementations driven by the manufacturer, who then said, "Here's the capability we have." We've also been brought into deals by other electrically conductive ink manufacturers. We're open to all of these kinds of engagements, and that's one of the things that's interesting about this.

We're well aware of the challenges in pushing technology, and we think we have a unique value proposition with the history of the company, the engineering capabilities of our team, and our materials processing background. I'm so thrilled and honored to be able to work with these folks every day. It's delightful to be able to work with customers; it makes us feel good that we can help.

Matties: Is this equipment conveyorized?

Farnsworth: The production tool that we're launching this summer is conveyorized. It's fully SMEMA compliant and designed to fit inline with a manufacturer's existing hardware.

Matties: Are there any inspection modules attached, or do your customers care about that function?

Farnsworth: Our initial product is not launching specifically with an inspection module, but we have the capability to include that, and we can incorporate that as part of any specific production implementation.

Photonic soldering allows standard lead-free solder to be cured on low-melting-point plastic films in a matter of seconds.

Matties: I would think that with Industry 4.0 and the smart factory, you're considering all of that in your software integration.

Farnsworth: We're learning a lot, and we have a product roadmap. We have two or three customers who are pretty vocal in asking when their tools are going to be ready. We're focused on getting a baseline functionality deployed for them, and it will be neat to see where the market evolves and what kind of functionality gets worked into our product roadmap.

Matties: In what region is the first equipment being placed?

Farnsworth: The first tools are going to Europe, interestingly, and the U.S. and Asia.

Feinberg: Gentlemen, thanks for your time. This has been very informative.

Farnsworth: You're welcome.

Ghosh: Thank you. SMT007

Solutions for Customer Support During Social Distancing

The Mannifest
Feature Column by Chris Ellis, MANNCORP INC.

In this difficult time caused by the COVID-19 outbreak, businesses are being forced to adapt. Business is not as usual, and as a medium-range machinery supplier, we at Manncorp and our customers have come to appreciate the benefits of remote services.

Free, remote services have always been included in our model. This allows the machines to be up and running faster, solving any difficulties that face a customer running a new machine, while also eliminating the time and expense of sending a technician. However, this recent crisis has led to our team brainstorming some innovative new ideas.

As on-site staff is reduced across the nation, exceptional customer service has become necessitated. How we are meeting this high demand is by providing new training videos, direct contact with customer service representatives, and real-time help through TeamViewer.

Our videography team has been producing new videos that walk the viewer through the mechanical and software set-up of our machines. These videos cover information on pick-and-place machines, stencil printers, reflow ovens, and even our AOI machines for self-installations; they also demonstrate how to

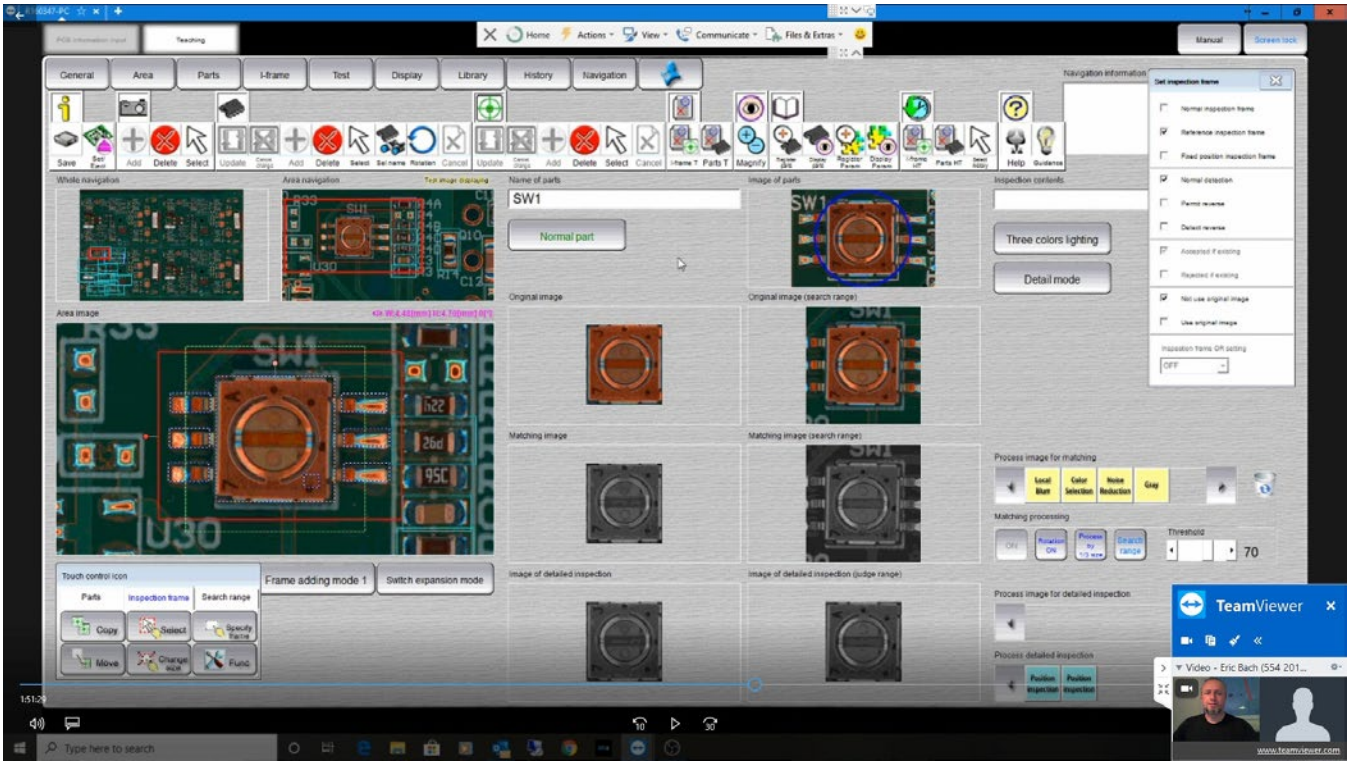

Figure 1: Remote AOI training.

Smart manufacturing processes generate terabytes of data. However, approximately 70% of the data is not used due to the lack of an easy platform that will leverage the data in an intelligent manner to drive business decisions. With Siemens digital solutions you can get insights and optimize productivity to become a best-in-class manufacturer.

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attach accessories and remove shipping brackets. We even have tutorials on how to make time-saving programs, create vision files, and program a feeder.

Having done remote installations of our AOI machines for years has allowed us to fluidly adapt under the current conditions. The addition of videos and the advancement of instant-help technology has allowed us to go further. If the videos do not provide everything a customer may need, our team of experts can access the machine through screen controlling. This allows us to diagnose anything that may be going wrong and apply a solution in real-time. In some cases, spare parts may be needed, and we can ship them overnight, allowing for a quick fix.

Figure 2: Online training on SMT fully automatic stencil printer.

Customers who use SMT equipment often wear many hats at their company. With this in mind, we have designed resources to help any customer set up and run a high-functioning machine. If needed, our senior tech can remotely train customers at a mutually ideal time. This training covers important subjects such as creating a file for each component, detecting problems like wrong parts, and ensuring correct orientation and sufficient solder paste.

Too often, an SMT line functions at only 40–50% of its capacity. But we know that if each machine is optimized for speed and correct placement, that average can be increased drastically. By solving common problems, more people can reap the benefits of their initial investment.

Common issues we see are:

- Incorrect programming of vision files or general programming issues for pick-and-place machines
- Board support issues, incorrectly programmed squeegee settings, or simply not having a high-quality stencil in the stencil printer
- A lack of training on correct profiling in the reflow oven

By interacting with knowledgeable staff members and watching our videos, customers can experience quick solutions. The result will be a high yield from the whole line-up. Without defects occurring, costs will be lowered, and fewer boards will be wasted. Through phone support or chat directly on a machine's computer monitor, we can offer more specific advice.

We have interacted with many companies dedicated to directly fighting the COVID-19 crisis. Northwestern University, who is working closely with Sibel Medical—a manufacturer of remote monitoring systems—is one of our most recent customers. Their remote monitoring systems have been identified by the U.S. FDA as critical technologies in the battle against the epidemic. These systems provide ICU-grade measurements of heart rate, respiratory rate, temperature, and blood oxygenation levels through a wireless, wearable format.

After the installs at Northwestern University, fine-tuning of the equipment was required,

and we were able to conduct these services remotely. The results were so positive that the university has decided to order a second production line.

Serving companies and organizations that are critical to our national infrastructure is crucial during this difficult time, and many customers are involved in government and military work. Most recently, we helped a contractor in Minnesota working for Naval Surface Warfare Center IHEODTD—a key component of the Defense Industrial Base.

When working with military contractors, personnel are often unable to enter facilities, and the organizations require remote contact alternatives. Working with companies housing sensitive information or hazardous products is one way that remote service will continue to be necessitated even after the stay-at-home order is lifted.

This is what we are doing at Manncorp. Hopefully, by hearing about our methods, other companies can develop their own solutions for remotely helping their customers. We urge companies in a position like ours to implement virtual or remote servicing methods in an effort to meet government guidelines. When this crisis has passed, businesses will open again, and it will be due to those who have done the vital work to keep things going in the meantime. **SMT007**

Editor's note: Written by Emmalee Gagnon with technical expertise from Chris Ellis.

Chris Ellis is a sales manager/engineer for Manncorp Inc. To read past columns or contact Ellis, click here.

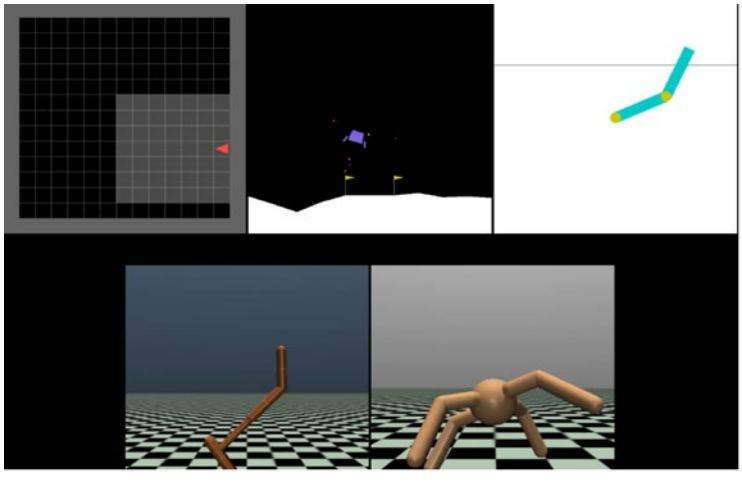
Automating the Search for Entirely New 'Curiosity' Algorithms

Driven by an innate curiosity, children pick up new skills as they explore the world and learn from their experiences. Computers, by contrast, often get stuck when thrown into new environments.

To get around this, engineers have tried encoding simple forms of curiosity into their algorithms with the hope that an agent pushed to explore will learn about its environment more effectively. An agent with a child's curiosity might go from learning to pick up, manipulate, and throw objects to understanding the pull of gravity—a realization that could dramatically accelerate its ability to learn many other things.

In recent years, the design of deep neural networks—algorithms that search for solutions by adjusting numeric parameters—has been automated with software like Google's AutoML and auto-sklearn in Python. That's made it easier for non-experts to develop AI applications. But while deep nets excel at specific tasks, they have trouble generalizing to new situations. Algorithms expressed in code in a high-level programming language, by contrast, have the capacity to transfer knowledge across different tasks and environments.

MIT researchers created a "meta-learning" algorithm that generated 52,000 exploration algorithms. They found that the top two were entirely new—seemingly too obvious or counterintuitive for a human to have proposed. Both algorithms generated exploration behavior that substantially improved learning in a range of simulated tasks, from navigating a two-dimensional grid based on images to make a robotic ant walk. Because the meta-learning process generates high-level computer code as output, both algorithms can be dissected to peer inside their decision-making processes. (Source: MIT)



Indium Metal Forecast: Supply Chain Strong, Demand Continues to Grow

Article by Donna Vareha-Walsh
INDIUM CORPORATION

Indium is a critical metal for the indium-tin oxide (ITO) market and other coating applications. Donna Vareha-Walsh—director of sales and global supply chain and trade compliance at Indium Corporation—describes the plentiful global supply of indium and its recycling loop, examines indium's history of price volatility and the market reactions from the recent Fanya Metal Exchange auction, and provides an overview of indium supply and demand drivers, as well as the impact of recycling efforts.

Indium pricing has been steady over the last few years through 2020, even under the pressure of an ongoing global pandemic. This year, indium has averaged $150 to $165 per kg based on Fastmarkets MB's current market pricing.

Indium has had a volatile past with the increases driven from liquid-crystal display (LCD) growth in the early 2000s, import and export taxes placed on the metal by China, and then the price run-up from the Fanya Metal Exchange. Figure 1 shows a good representation of the prior market volatility that has subsided as we have seen steady prices over the last few years.

The supply chain of indium is global in nature. Based on the USGS, 760 tons were produced in 2019. Additionally, there is a strong reclaim loop constantly feeding the supply chain.

The demand for indium is mainly in the form of ITO, which is used in LCD screens for flat-panel devices—such as mobile phones, computers, and televisions—and in solder, alloys, electrical components, and semiconductors.

The compound annual growth rate (CAGR) for global ITO will increase by 7.7% by 2022, with growth coming primarily from China

Figure 1: Indium metal market prices.

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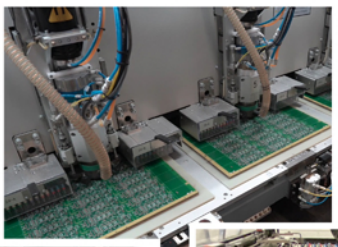

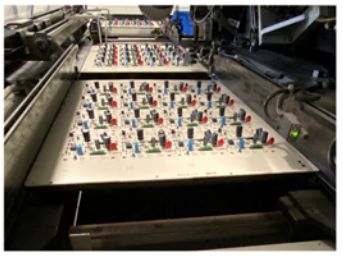

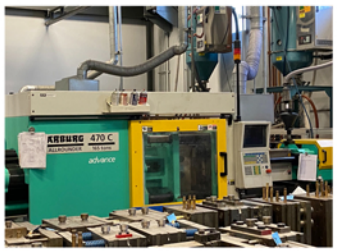

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and South Korea. The main growth drivers for indium demand come from larger screen sizes, television shipments, small moves to organic light-emitting diodes (OLED), growth in quantum dots, and the developed world deployment of 5G. The caveat is, as the price of indium increases, so do the R&D efforts by display companies to use thinner coatings or alternatives.

ITO alternatives have been met with limited adoption in the display industry. Alternative transparent conductors—such as silver nanowires, carbon nanotubes, graphene, and metal mesh grids—will eventually find their niche application, but it won't be in the non-touch display back panel anytime soon. None of these alternatives are a drop-in replacement for the entrenched and established ITO infrastructure and 30-year processing "know-how" of ITO.

Closed-loop ITO target recycling promotes responsible use of indium and further extends value and efficiencies to our display customers, making it hard for these alternative technologies to find a competitive entry point. While Indium Corporation closely monitors alternative transparent conductor technologies, near-term opportunities are limited. Indium Corporation has an indium recycling facility in South Korea that supports the closed-loop system.

The supply chain for indium is strong and able to meet demand. The supply can also expand to meet increased or new demand given total proven reserves equal to 50,000 MT, equivalent to 50–100 years of consumption. Additionally, the indium supply in zinc and copper concentrates is plentiful. Extraction and refining can be expanded to meet the demand for emerging technologies. **SMT007**

Sprayable User Interfaces

For decades, researchers have envisioned a world where digital user interfaces are seamlessly integrated with the physical environment until the two are virtually indistinguishable from one another.

Recently, a group of researchers from MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) came up with SprayableTech—a system that allows users to create room-sized interactive surfaces with sensors and displays. The system, which uses airbrushing of functional inks and enables various displays, like interactive sofas with embedded sensors to control your television and sensors for adjusting lighting and temperature through your walls.

SprayableTech lets users channel their inner Picassos: After designing your interactive artwork in the 3D editor, it automatically generates stencils for airbrushing the layout onto a surface. Once they've created the stencils from cardboard, a user can then add sensors to the desired surface—whether it's a sofa, a wall, or even a building—to control various appliances like your lamp or television.

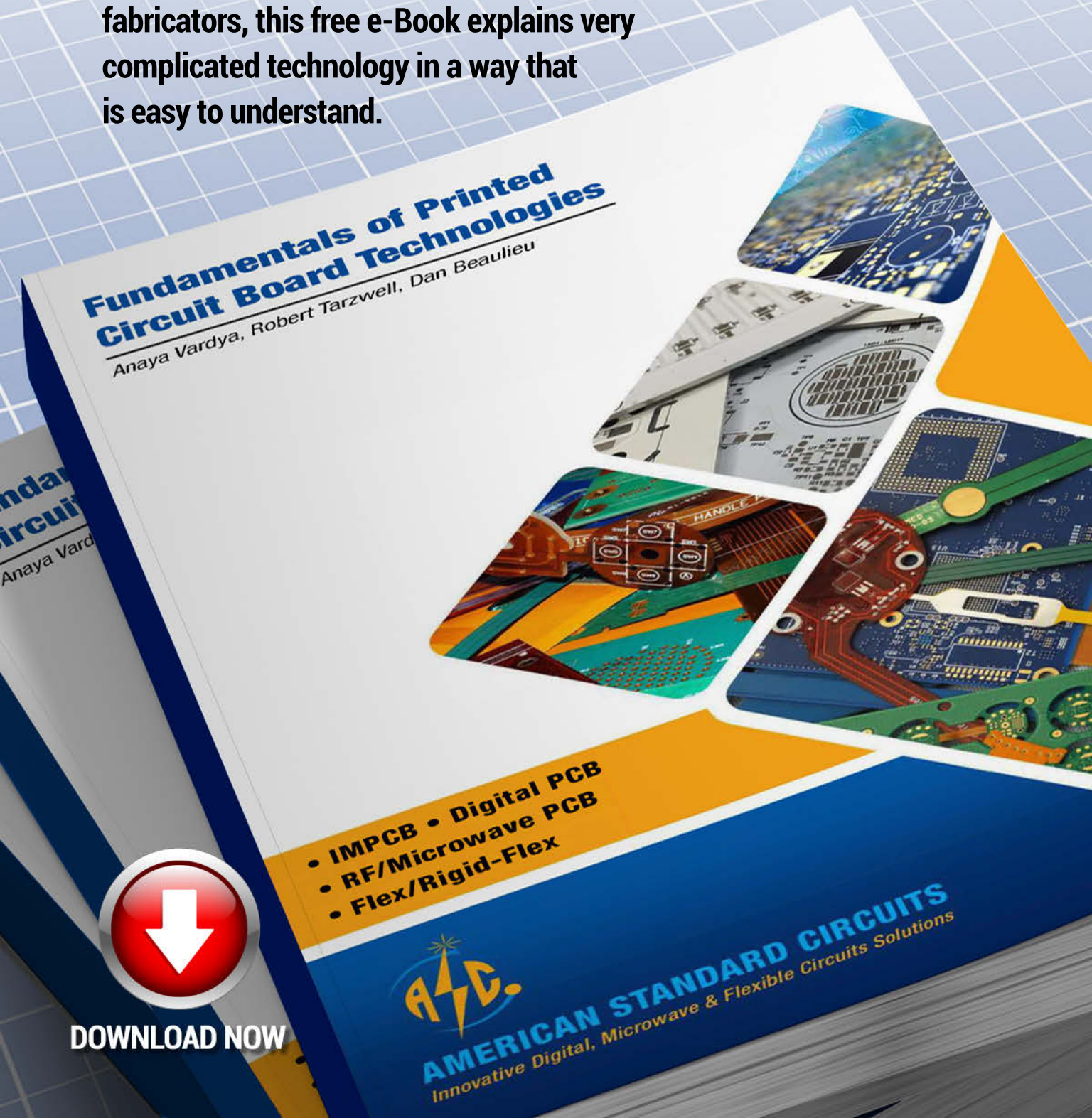
"Since SprayableTech is so flexible in its application, you can imagine using this type of system beyond walls and surfaces to power larger-scale entities like interactive smart cities and interactive architecture in public places," says Michael Wessely, a postdoc in CSAIL and lead author on a new paper about SprayableTech. "We view this as a tool that will allow humans to interact with and use their environment in newfound ways."

By using the airbrush technology, they're no longer limited to the size of the printer, the area of the screen-printing net, or the size of the hydrographic bath, and there are thousands of possible design options.

(Source: MIT)

Everyone in the industry should get their hands on this book.

A "must-have" for PCB designers, OEMs and fabricators, this free e-Book explains very complicated technology in a way that is easy to understand.



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Supplier Highlights

Siemens and Valor: Two Complementary DFM Technologies ▶

Before IPC APEX EXPO kicked off, Andy Shaughnessy attended a Siemens seminar in San Diego on smart manufacturing for electronics and the integration of technologies from Siemens' digital industry software and Valor. Afterward, Andy spoke with Andy Farrington, director of portfolio development for the Americas, about the event, as well as some of the hot topics and solutions that the speakers addressed.

PVA Manufactures COVID-19 Emergency Ventilator ▶

PVA, a global supplier of automation equipment servicing the electronics, medical device, telecommunications, semiconductor, and defense industries, has rapidly manufactured an emergency ventilator to help combat supply shortages during the coronavirus (COVID-19) pandemic.

Rehm Announces Development of New Production Technologies for Solid-state Batteries ▶

Rehm is working on the development of new production technologies for solid-state batteries as part of a research cooperation.

Panasonic: From Hardware to Solutions and Data ▶

In this video interview, Managing Editor Nolan Johnson speaks with Sean Murray—director of sales, service, operations, and logistics process automation at Panasonic—about the company's focus on software and information management on top of their long history in hardware and equipment.

EPTAC Preparing Young People for Future in Industry ▶

In this video interview from the show, Guest Editor Kelly Dack and Leo Lambert, VP/technical director of EPTAC Corporation, discuss the impact of internships and apprenticeships, the importance of IPC specifications, the effectiveness of certification.

Sono-Tek is Joining the Fight Against COVID-19 ▶

Sono-Tek Corporation, the leading developer and manufacturer of ultrasonic coating systems, announced that it joined the fight against COVID-19 in several ways.

Mycronic Publishes the 2019 Annual and Sustainability Report ▶

Mycronic AB publishes the 2019 Annual and Sustainability Report. The Annual and Sustainability Report is available on the company web site as a PDF.

The Foundation of Industry 4.0 ▶

When adopting IoT solutions, start with three main considerations. First, assess which parts of the production cycle can be automated and/or monitored most effectively with IoT devices connected to an analytics platform. IoT technology should be matched to the production cycle of your operation.

Electrolube Resin a Success for Two Wheeler EV Batteries In India ▶

Electrolube, the global manufacturer of specialist electrochemicals, announced the success of its ER2221 resin for the protection of EV batteries in popular two-wheeler vehicles in India.

alpha

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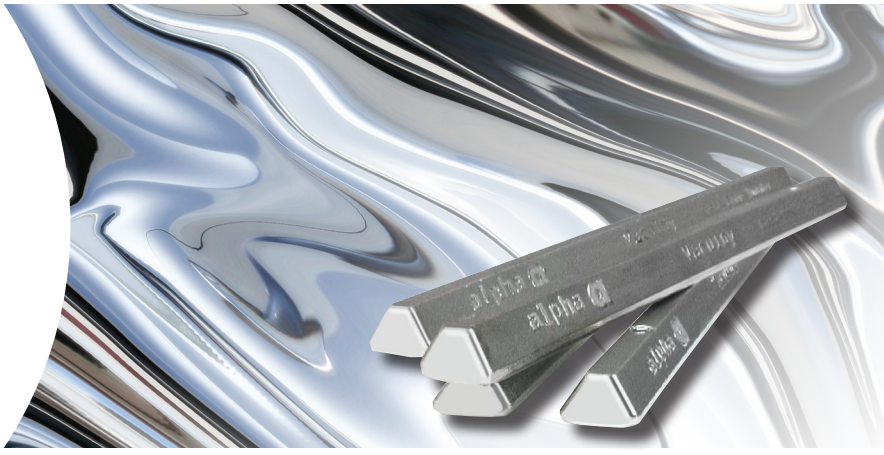

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Current Advances in Soldering Technology


Clemens Jargon

Feature Interview by Nolan Johnson and Barry Matties
I-CONNECT007

Nolan Johnson and Barry Matties spoke with Clemens Jargon to explore some of the issues and dynamics that he sees from Mycronic's point of view in advanced soldering technology. They cover trends in the industry, jetting vs. stencil printing, and the many different solder paste options.

Nolan Johnson: There have been a lot of changes in soldering technologies and the development of respective materials, including the functions and machinery supporting the process of getting components soldered onto a board. How would you assess the current development work and advances and challenges for depositing solder paste on PCBs?

Clemens Jargon: That's a very good question, which hits to the point why Mycronic is doing jet printing rather than stencil printing. When you look into the standard stencil printing process, which is one of the most aged technologies within the entire SMT process, the stencil printing process is prone to defects.

There are a lot of reasons for insufficiencies, such as bridges in depositing solder paste or opens. No doubt, there are also material concerns. When you are able to avoid these inherent stencil printing defects, then you can significantly improve the entire process quality. Solder paste material issues are hard to adjust and hard to change, but for anything that is in our control, meaning the depositing process, we can make very effective changes. Our goal is to eliminate 90% of paste-related issues; when we reach this, we can turn >50% of defective boards into perfect products.

We want to increase the first-pass yield for our customers, that's why we focus on jet printing. Instead of using stencils, we jet print any dots needed on PCBs. We avoid stencil printing and any of its related issues, which helps to avoid costs for buying stencils, which also includes support costs for storing and cleaning stencils. The entire jet printing process is a much more modern way in comparison to stencil printing to improve the first-pass yield, and the quality of our customers' finished goods.

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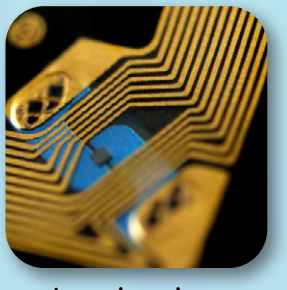

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And we have been able to improve even more. You may remember we acquired the company Vi Technology in France a while ago. They had special competence in SPI and AOI technologies. The solder paste inspection (SPI) technology was extremely important and relevant for us because we can now combine the jet print technology with an advanced inspection technology and offer our customers a closed-loop solution, a tangible step forward, providing an Industry 4.0 contribution.

When every board matters and customers would like to have 100% trust in their solder depositing process, they buy the connected solution—the SPI behind the jet printer. The SPI recognizes after jet printing any deviation from being perfect, creates a potential necessary repair file, and returns this file back to the jet printer. When you bring back the same board in the jet printer, based on the barcode, it recognizes if a board needs to be repaired; in this case, it only executes the repair file, the board is perfect, and you avoid waste.

When every board matters and customers would like to have 100% trust in their solder depositing process, they buy the connected solution—the SPI behind the jet printer.

We can also do the same combining a stencil printer, an SPI machine, and a jet printer because sometimes the line speed demand is so high that customers still have to operate stencil printers. Then, you can, as a next process step, inspect the printed board with our SPI. It may recognize that there is some deficiency in the printed result. Again, the SPI creates a repair file and sends it to the jet printer. In the next process step, the board goes into the printer where it will be repaired. That means the combination of technologies like the SPI and the jet printer delivers higher quality and measurable improvement than ever possible when relying on the standard stencil printer.

Johnson: I'm imagining what that would look like on the manufacturing floor. You're running boards through the jet printer and looking at the results of that printing process. Some boards are going to go straight through, and some boards are going to take two passes through the machinery with the help of an operator.

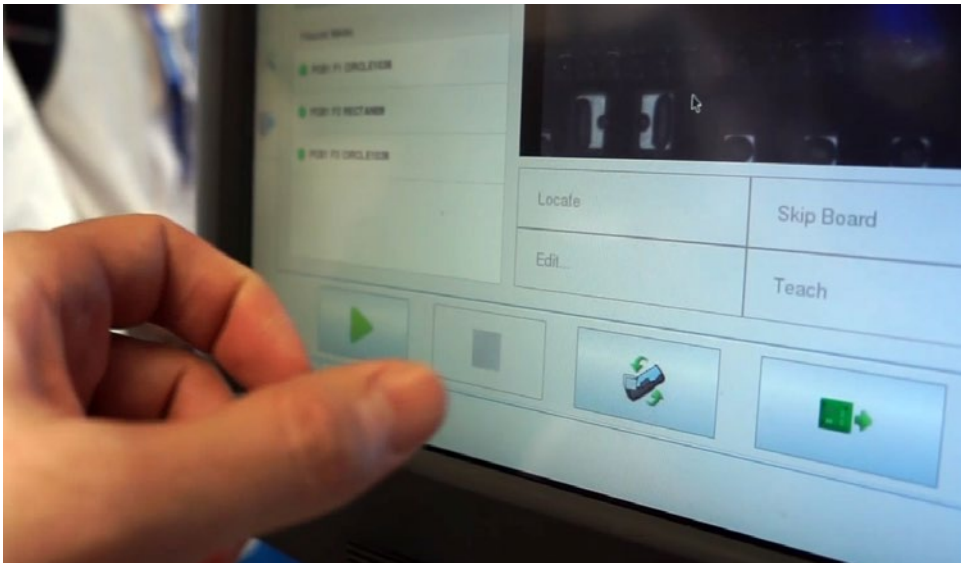
Jargon: Yes, you can connect the stencil printer, the SPI, and the jet printer, and—in the ideal case—the PCB passed straight through the line, it stencils, inspects, and repairs. In case you set up your line stencil-free and invest only in jet printing and SPI, you set up the process differently. When the SPI identifies a deficiency and alerts a defect on the board, the operator can manually bring the board back in the jetter for repair. Some customers have installed another jet printer behind the SPI; they do not need to touch the board, and it goes automatically and straight in the repair process. All those combinations are possibilities. It depends on the setup the customers install on their factory floor.

Johnson: Obviously, software—programming the inspection routines—becomes a critical part of the process.

Jargon: That's correct. The machine has more mathematics and intelligent algorithms than hardware. The technology to print is a combination of very reliable hardware and advanced software. You need a very robust platform with a high-quality gantry, unique ejector technology, and operating software. We are jet printing now since 2005.The software is a very important part of the entire Mycronic solution, which we have continuously improved.

We are printing solder dots on the fly. That means the ejector is continuously moving while we deposit material. The algorithm in the software calculates in advance the ballistic

curve of the dots before they drop on the PCB; we are not able to wait while depositing. We are constantly moving and shooting, but we are still able to be so precise and accurate. This is due to very high competence in the software, combined with the very robust and reliable hardware and the unique jetting technology.



Mycronic jet printer demo screen.

Johnson: Undoubtedly, you work very closely with the solder paste suppliers. As a jetting technology company, what are the issues or the challenges right now with solder paste materials?

Jargon: That question hits to the point I described before, we offer a combination of hardware, software, and the ejector technology. But the fourth element missing is the solder paste. Not all pastes are jettable, so we had to work intensively together with all relevant solder paste manufacturers to get high-quality jettable paste. Not all paste suppliers have been able to provide jettable paste. We have recognized that the suppliers need to have perfect control of their paste production process. They cannot allow any process deficiencies; there is no way to compromise when making a perfect printing solder paste.

We have started working in the early days in joint cooperation with the solder paste manufacturers. We even had to hire chemical experts to talk with them in the same language and ensure that the solder paste works in perfect harmony with our ejector technology. When everything goes so fast and has to be so precise, there are also certain risks that need to be eliminated. The ejectors can clog, for example, and the material gets stuck in the ejector.

There's a risk of having little satellites when you print solder paste. This means when you print, the paste may sputter a bit, and then you have satellites, meaning tiny dots, which you do not want to have. There's a risk that the paste has the wrong viscosity and that you observe voids. We have learned these things can have a negative impact on the quality; therefore, we decided we had no other choice but to work very closely with our partners.

In the meantime, almost all solder paste manufacturers have recognized that the trend goes more and more toward providing jetting paste. They all work very closely with us and have learned how to improve over time. I can give you an example. We worked with one of the paste suppliers; they provided us with paste out of their R&D lab, and when printing, the result was perfect. Then, they developed larger batches, and we suddenly observed problems. The ejectors clogged.

We recognized that the mixing process of larger batches had been different from the mixing process of the small batches in the R&D labs. The process was not perfectly in control and had an impact on the paste and printing quality. Our partner readjusted the mixing process for bigger batches very fast, and we came back to perfect printing results. The solder paste manufacturers are very important partners for us to make sure that the printing process deliverers the highest accuracy and perfect quality.

Mycronic MY700 with operator.

Barry Matties: When a customer has a quality problem, do they call you or the paste supplier?

Jargon: It depends. The one who creates the problem should be the one who solves the problem. Often, customers come to us when something goes wrong, but in the meantime, we can determine where the problem might be and refer immediately to the paste supplier, if necessary. But when we see a problem in connection with our machine, or when we see that we can help the solder paste manufacturer, then we do that. This setup has to run in perfect harmony.

Johnson: Having the SPI included in this line, does that help give diagnostic information to more quickly figure out what went wrong with the solder paste?

Jargon: When we inspect boards, we analyze the printing result. As a consequence, we can also track back if the printing pattern is potentially affected by wrong or bad solder paste and tell the supplier, "Let's get together and see what we can do to improve."

Johnson: Right now, at Mycronic, where are you putting most of your R&D attention? What are your priorities?

Jargon: The priorities are in optimizing the entire process and trying to eliminate as many issues as we can. We see a continuous trend toward further miniaturization and into more complex PCBs. When the COVID-19 pandemic is over, we potentially see an enormous push for 5G technologies. 5G boards are increasingly more complex than others before. Our R&D is focusing on being much more flexible to support the trends that we see right now, such as having smaller dots and being flexible in the way we deposit the material. When customers want to handle very complex boards and still use the stencil printing process, they often have to use step stencils, but those can be very difficult to handle. With jet printing, we can avoid any need for step stencils.

We're also focused on a broader variety of pastes for the jet print technology. There is strong demand right now, such as for low-temperature solder pastes. We work with almost all our partners on how to qualify and how to certify low-temperature solder paste for our jetter. We work on cleanable, water-soluble pastes because we see also here a strong demand and trend. Water-soluble paste is a difficult material to deposit because it's a very aggressive material. You need to develop your ejector technology to make it fit for these demands. We also spend a lot of R&D resources on further machine integration and full-line solutions.

We see industry standards getting more and more relevant, and we see a continuous demand for a higher level of factory integra-

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– Felix Valenzuela, Director of Engineering, Molex

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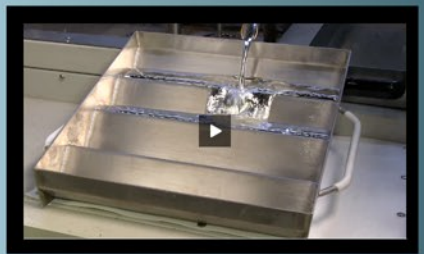

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tion. This is an area where our smart engineers spend a lot of their time. There is also a continuously increasing trend toward more advanced software. Hardware is under control, and now the question is, "How can we support our customers with highly intelligent software solutions?"

Matties: You've mentioned a number of different types of paste. How many jettable paste compositions are out there?

Jargon: First of all, there are a couple of very large and worldwide relevant suppliers, and we work with most of them. But there are also lots of smaller ones when you look at China, for example, which is a very relevant market for us. There are a lot of local Chinese suppliers that work in different industry areas. Each of these manufacturers has different pastes for different applications. Sometimes, they even customize their paste for certain applications.

When large mobile phone manufacturers develop their next-generation mobile phones, they sometimes have certain applications with very special demands on paste that are not yet available. They work together with paste manufacturers and request, "Can you customize your paste to my requirements?" They find out these applications cannot be done with a stencil printing process; they are forced to use a jetting process. Then, they come to us and share their demand, "We need to customize the paste. Can you make sure that these pastes can be qualified as a jettable paste in your printer?"

Matties: You're saying there's a lot of variety of pastes out there, and an assembler will choose the paste based on the technology that they're using at their facility. Is it basically the same jetting technology, or do they need to change any of the heads for different pastes, or how does that work?

Jargon: We have a spectrum of different ejectors that are set up on more or less the same ejector technology. Sometimes, you have to look into what parameters you can change and how, and if it's reasonable to change, then we do this together with the paste manufacturers. But for the standard pastes, there's rarely a need to adjust the ejector technology. The necessary but sometimes incremental changes are happening on the paste side.

Sometimes, you have to look into what parameters you can change and how, and if it's reasonable to change, then we do this together with the paste manufacturers.

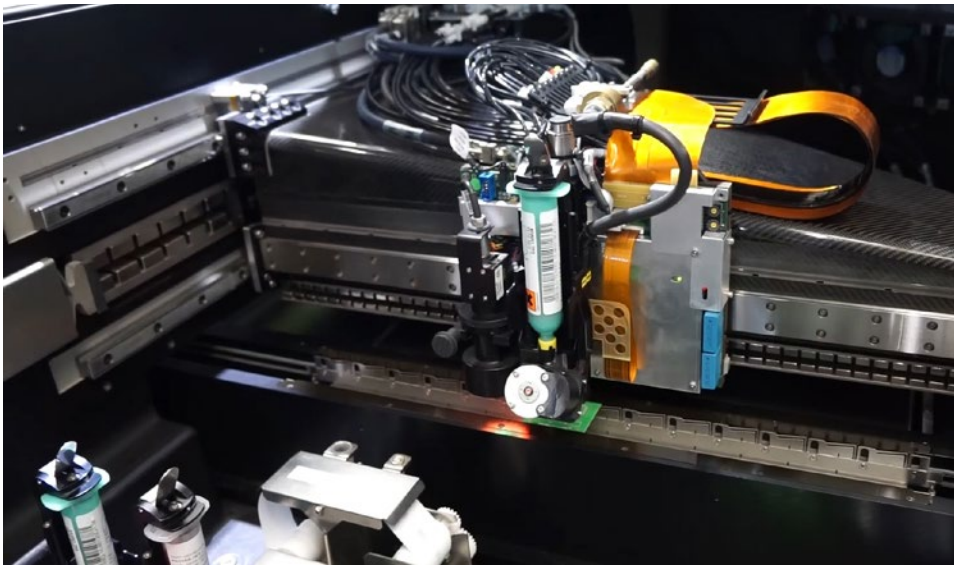
There is one more aspect: Storing of solder pastes is a bit challenging. You have to store the paste under certain conditions (i.e., special temperatures). Otherwise, it's aging, and the use expires. We have jointly developed a paste with one of our partners, which can be stored at room temperature. The supplier calls it the game-changer solder paste. They developed the paste explicitly together with us because they wanted to offer a jettable paste that also provides their customers with easier storing capabilities over long periods of time. This is another example of where you have to work together to get a perfect, high-quality solution.

Matties: There may be process changes, but once they buy the jet equipment, they deal with the solder paste suppliers.

Jargon: Yes. We provide the reference technology from the hardware/jetter perspective, and then they further develop and adjust their paste.

Matties: Speed has always been an issue for jet technology. How are you answering the demand for high-volume throughput?

Jargon: We can shoot with 300 hertz, which is a million dots per hour. That is a phenomenal speed, but it's not as fast as stencil printing. When you do standard PCBs in high-volume applications—where you don't change the PCB design at all, always the same board—you might still prefer using a stencil printer. We would love to completely eliminate stencil printing in any factory, but we also have to be fair and realistic. To be even faster than 300 hertz and keep the same quality is a real challenge, and it might even not make sense. There is still room for stencil printing technology in high volume when changing over doesn't matter. Developing a machine even faster might increase the price up to the point that it wouldn't be competitive anymore.



Mycronic jet printer.

Matties: The economics of it would be in the quality of the board. If you're suffering from field failure, then the cost may be warranted for jet printers.

Jargon: Yes. When high-volume customers also want to rely on the benefit of jet printer technologies, they combine it and set up an add-on solution. The high volume solder paste deposition will be done by the stencils. They position our jet printer after the stencil printer, and any more challenging patterns or deposits that can't be done by the stencil printer will then be done by the add-on jet printer.

Johnson: In a high-mix, low-volume production environment, doing all of your solder paste work with a general technology seems to make sense because it would be easy to adjust to your product mix, and keep production going. In a high-volume, low-mix environment, it makes sense to start with a stencil print, do an inspection, repair any mistakes from the stencil print using the jet technology, and get an automated first pass. At what point is the trade-off? How high-volume do you need to be when you start changing from jetting to stencil plus jetting?

Jargon: You could do this step by step. As you said, in a high-mix, low-volume area, we already have a couple of customers around the globe who eliminated stencil printing completely. When you need more speed and go toward mid-volume, then you can connect two jet printers together. We call it a twin solution. We can balance two printers in line, which means four printing heads, this gives even more speed supporting the mid-volume market

When you look at the demand of a high-volume EMS company that produces smartphones or other high-volume industrial applications, this jet printer speed might not be sufficient. But you can connect three jet printers. When there are three jet printers this means six heads connected and balanced, the economics might already be challenging. In this case, customers better decide to install an add-on-solution. For anything in high-mix, low-volume, and entry mid-volume, this can be done with jet printing. When you go beyond that, you have to incorporate stencil printing.

Matties: Thank you, Clemens.

Jargon: Thanks. **SMT007**

Update Your Business Contingency Plan

Operational Excellence

by Alfred Macha, AMT PARTNERS

With the unprecedented events associated with COVID-19, companies are facing worst-case scenarios and looking at ways to manage work stoppage or limited production for essential manufacturing needs. This column provides a practical guideline to create or update your business contingency plan to help you manage your business during a crisis situation.

An effective business contingency plan consists of two categories: business continuity and disaster recovery. Business continuity provides you a structure to identify critical functions in the organization required to execute your business plan over time. On the other hand, a disaster recovery plan is a process to help your organization navigate adverse situations to help your business stay afloat.

Business Continuity

Business continuity consists of seven essential elements in a manufacturing organization.

1. **Governance:** Define the roles and responsibilities of executive leadership. Define a back-up plan in case you have departures of leaders in the organization.
2. **Personnel:** Define talent acquisition and development of employees. The objective is to retain top performers and continuously develop skills in the workforce.
3. **Manufacturing Facilities:** This section covers many areas within manufacturing operations. At a minimum, identify all key equipment and back-up plans in case of malfunction and requirements to continue to have utilities, equipment maintenance, compliance with regulations, and security to support operations.
4. **Technology Roadmap:** Define current and future process capabilities. Identify the direction that the organization plans to take to sustain or increase revenue based on competitive technological advantages. Consider including the protection of intellectual property.

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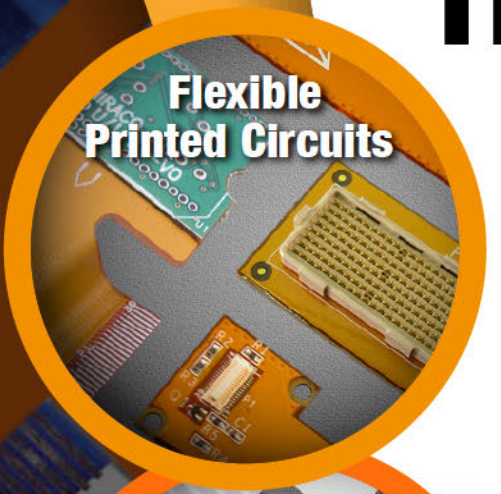

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Risk	Probability of Occurrence	Impact of Occurrence	Risk Mitigation Plan	Recovery Plan	Leadership	Reference Documentation

Table 1: Disaster recovery planning.

5. **Supply Chain:** Securing a supply chain to meet current and future business demands is paramount. Identify all key vendors and possible new vendor qualifications to confirm that the supply of components, raw materials, and sub-assemblies is secure to ensure continuity of your operations.
6. **Information Systems:** Develop a solid data storage back-up system and establish external support to maintain your information systems. The ongoing development of information technologies requires partnering with a reputable vendor that can support your information technology systems as new software applications are made available.
7. **Customer Management:** Develop customer management processes to secure key accounts for your business. Include a business development plan to acquire new strategic business for future growth.

Disaster Recovery

Disaster recovery planning is risk-based and can have multiple factors to consider. The recommended approach is to prepare a table based on specific risks and define a risk mitigation plan to address each risk. Consider using Table 1 as an example.

1. Risk: Identify risks that could affect your operations. Common risks include:
   - Supplier ABC obsoletes a particular component
   - The company email or intranet is disrupted
   - An employee with unique skills or knowledge leaves the organization
   - Equipment failure of specialized technology
   - A key customer moves manufacturing orders to a competitor
2. Probability of Occurrence: Consider having five levels of occurrence (90% = very likely, 75% = likely, 50% = possible, 25% = unlikely, 10% = very unlikely).
3. Impact of Occurrence: Consider having five levels of impact (5 = severe impact, 4 = high impact, 3 = moderate impact, 2 = limited impact, 1 = insignificant)
4. Risk Mitigation Plan: Prepare a specific action plan to prevent or minimize the risk from occurring.
5. Recovery Plan: Prepare a recovery plan to remedy adverse outcomes when risk occurs.
6. Leadership: Clearly identify responsible individuals within the organization to lead risk mitigation and recovery plans to address a specific risk.
7. Reference Documentation: Reference existing procedures, standards, manuals, or other documents that provide supplemental information to help with risk mitigation and/or recovery plans. SMT007

Author's Note: Fundamental concepts and methods illustrated in this column were derived from the following books:

1. *Business Continuity Management: Global Best Practices, 4th Edition* by Andrew N. Hiles and Kristen Noakes-Fry
2. *The Power of Resilience: How the Best Companies Manage the Unexpected* by Yossi Sheffi
3. *Crisis Management: How to Develop a Powerful Program* by Regina Phelps

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Electronics Industry News and Market Highlights

Robotic Process Automation Market Size to Witness a CAGR Growth of 33% During 2019 to 2029, Opines Fact.MR ▶

Organizations worldwide are identifying processes that can be automated. This is in response to the increase in productivity and efficient use of resources that robotic process automation offers.

Allied Electronics & Automation Announces Three New Senior Executives to Lead Corporate Functions ▶

As part of its commitment to hiring high-performing, diverse, and experienced leaders, Allied Electronics & Automation recently named three new executives to lead the company's finance, human resources, and marketing functions: Manisha Kadoche as chief financial officer, Katie Cartwright as vice president of human resources, and Jessie Dearien as vice president of marketing.

Keysight's 5G Test Solutions Selected by DEKRA ▶

Keysight Technologies Inc. announced that DEKRA selected Keysight's end-to-end test solutions to certify 5G new radio and vehicle-to-everything (V2X) devices, in compliance with a wide range of requirements, to improve safety in human interaction with technology, including vehicles.

Mobile Robots and Autonomous Vehicles: Coronavirus Pushes Logistic Automation up the Agenda ▶

IDTechEx has been examining the technological and commercial trends in this field for several years. Their report "Mobile Robots, Autonomous Vehicles, and Drones in Logistics, Warehousing, and Delivery 2020–2040" focuses on the automation of movement in every step of the logistics and delivery chain ranging from a warehouse or a factory to the delivery of goods to the final customer destination.

BrainChip and Socionext Provide a New Low-power Artificial Intelligence Platform for AI Edge Applications ▶

BrainChip Holdings Ltd—a leading provider of ultra-low-power, high-performance AI technology—announced that Socionext Inc.—a leader in advanced SoC solutions for video and imaging systems—will offer customers an artificial intelligence platform that includes the Akida SoC, which is an ultra-low-power, high-performance AI technology.

Amplitech Reports Record Revenue for 2019 ▶

Amplitech Group Inc. (AMPG) announced its results for the full year ended December 31, 2019.

Business as Usual at Hytera's Intelligent Manufacturing Center ▶

Hytera Communications—a leading global provider of private, professional communications solutions—has been able to keep its manufacturing systems working normally despite the threat posed to global supply chains caused by the COVID-19 pandemic thanks to its investment in intelligent manufacturing and supply chain solutions.

AT&T and Brain Corp. Are Meeting COVID-19 Challenges ▶

Data-intensive Internet of Things applications will enable robotics for cleaning, inventory delivery, and shelf-analytics for retailers and other essential businesses.

Fume Extraction in Electronics


Andy Mitchell

Feature Interview by Nolan Johnson
I-CONNECT007

I spoke with BOFA's Andy Mitchell about the current trends and challenges facing electronics manufacturing facilities with regard to fume extraction, fume management, and the current state-of-the-art soldering.

Nolan Johnson: Andy, introduce us to you and BOFA.

Andy Mitchell: My title is west regional sales manager. I'm responsible for both the technical side and the sales side for BOFA's customers in about 12 western states. BOFA was originally founded in Poole, England, and we're still headquartered in Poole. A lot of the local exhaust ventilation industry started in Europe and the U.K. because the EU had a lot of regulations that required it.

BOFA started about 33 years ago in the U.K. In the U.S., the company opened up the BOFA Americas division roughly 10 or 12 years ago. Probably the biggest footprint in the industry is in the laser coding and laser marking industry, then also the laser engraving and cutting industry. Those processes create a lot of fumes and particulates, that we're able to capture, run through filters, and exhaust clean air back into the room instead of exhausting it outside.

That same technology then lends itself to a lot of other industries, with electronics being a big one as well with either soldering processes creating the fumes from the flux vapor and the odors from conformal coating or cleaning processes. Also, there's some laser work in electronics as well, and then routing, removing boards from panels—both with a laser or even with a mechanical means; you create a lot of debris, and we have systems designed for removing that as well. With electronics, it's mainly the soldering side, or the conformal coating and chemical side where they come into play. Then, two years ago, we were purchased by Donaldson Corporation out of Minneapolis, Minnesota, so that's our parent company now. We're BOFA-Donaldson Company.

Johnson: There are fume extraction issues in the PCB fabrication industry as well, what

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with all the wet chemistries and the like. Do you have much presence in the printed circuit board fab facilities?

Mitchell: Not anything significant, and the wet part is the reason. The filtering technology we use doesn't like to get wet. We can take the gas vapor coming off of those processes, but if it's enough of a vapor that it's going to condense back into any kind of liquid, it gets out of our main work area. We do get into the component side of it. There are a lot of applications in that, and most of those are dealing with lasers of some kind.

Johnson: Right, such as vaporizing a lot of solid materials. Tell me a little bit about the technology for doing what you do and managing those sorts of fumes and vaporized items. What are the concerns?

Mitchell: At its simplest description, we create airflow with a motor blower, or some people call them pumps, that makes the airflow that draws the air from whatever area you're creating this material you want to filter. Let's say it's a laser and you're going to create enough airflow to draw the air from the laser, hold it into the extractor, and then it goes through typically three phases of filtration, which the first phase is a pre-filter—typically something around a 95% efficiency at 0.8 microns. Relatively speaking, we'd call those the larger particulates. It's going to capture those in the pre-filter. The reason for the pre-filter is it's going to take out most of the bigger stuff so that when you get to the next stage—which is the HEPA filter—you'll have less material going into it because HEPA filters tend to be more expensive, so you don't want them getting clogged up with large particulate that you can capture in a pre-filter first.

HEPA filters are 99.997% efficient at 0.3 microns, which is kind of the magic number people are worried about with the particulate size getting caught in your lungs and bloodstream, potentially causing a health hazard. The HEPA filter is designed to capture that material, and that's your second stage. The third stage is going to be activated carbon, and that's what's going to capture the gas and the odor mainly of the material you're working from. A lot of our extractors have two physical filters: the main filter case contains both the HEPA and the carbon. The prefilter is a separate filter case. There are two physical filter cases, but it's looked at as three stages of filtration.

The entire extractor is going to have the pump that creates the airflow built into that; the electronics that control the settings, the speed of your pump, and then your filters are all put into the same extractor that allows you to have everything fully contained. Essentially, you plug this into a power source and connect a hose from wherever the source of the particulate or fume is generated. More than half of the products that we're offering are being used at 120 volts. We have some of our larger units that require 220 volts, and we have one significantly larger unit that's 440 volts.

Then, the hose runs back into the extractor, so it pulls everything into that and vents it back out generally into the room. You could add a port to it to vent it out somewhere else

if you wanted to, or—in some applications—to circulate the air back into whatever chamber you were pulling air out of so you can have a closed-loop system.

Johnson: Is this typically installed with one unit per hood, or is it built into the central HVAC system?

Mitchell: The systems that we manufacture are designed to be task-oriented. You're going to put an extractor for each of those tasks. If you had five lasers that were all next to each other, and each laser needed about 200 CFM to pull the air out, you could put one extractor that's generating 1,000 CFM. Typically, we put one extractor on each one of those units to leave you a lot more flexibility that way. This isn't something that we're going to hook up to an HVAC system and try to pull the whole building into it. We're looking more at if you're hand soldering and putting an extractor with that operator or at least a hood with that operator. If it's an inline oven, we're going to hook up one extractor per oven, and then lasers are the same thing.

Johnson: Talk more about the dangers of the particulate that's being created: solder, solder fumes, flux, flux fumes, very small particulates, and vaporized solids from the lasers. What are the dangers to humans from those?

Mitchell: Essentially, you're looking at lung and breathing issues. With some of the chemicals that people work with, there can be either health limits to the amount of that material or even sort of allergic reactions to different chemicals that you're able to alleviate those.

Johnson: What are the current trends or challenges facing electronics manufacturing facilities with regard to environmental regulation and/or worker health regulation?

Mitchell: The first challenge is how you're going to capture it. If you're working with enclosed systems like lasers and ovens, it's much easier. If you're working with things that are more hand operations, you have to create ways to gather up that fume and particulate and get it drawn into an extractor.

Johnson: What are some implementations you see in the field right now?

Mitchell: If the unit that's creating or processing the material is enclosed, that's simple. There's generally going to be a port that's the vent, you connect the hose to it, and that hose also connects to our unit. If it's more of an open process—maybe an operator at a workbench hand soldering, touch-up conformal coating, or any of those types of operator processes—you're going to put either a flexible arm with a hood at the end of it that captures or have a smaller hood that you can configure onto the bench that creates the airflow and draws it in. The more enclosed that it gets, the better the capture is going to be—in part because you're removing the variability of the operator. If you have an arm with a hood at the end—which has been used for capturing solder fumes for the longest time—they're efficient when they're in the right place. In the right place means the operator has to have the board and the hood close enough to each other that it's drawing the fumes in.

Johnson: If you find that your work station is in a facility where you're close to a door, for example, when that door opens and closes, it changes the pressure and causes air nearby to move horizontally; now, the hood is no longer doing the job.

Mitchell: Right, or an operator is warm, so they get a little fan and put it on their bench and blow the air on themselves across their work surface—not that I've ever seen that happen before (laughs).

Johnson: There has been a lot of development lately in solder technology—changes to the flux, using fluxes in different ways, etc. Solders have gone from containing a lot of tin and lead to lead-free solders, which has shifted the working temperatures. Of course, smaller and

smaller solder ball sizes are appearing in some mixtures. Do these changes play a part in what kind of products you need to deliver to electronics manufacturers?

Mitchell: I would say in the bigger picture, if I'm hand soldering with lead-free solder or tin-lead solder, how I capture it is pretty much going to be the same. That lead-free solder probably has a no-clean flux on it with low solids, so it's putting out fewer particulates than the old tin-lead solder with 30% solids RMA flux, but I'm still going to capture that the same way. As things get smaller, in one small respect, you could say it makes it a little bit easier because you don't have to try to cover as wide an area. Parts are getting smaller and the boards are not significantly shrinking unless the end-product is a small product like a cellphone or something like that.

Johnson: It's the size of the grit that's used in the solder.

Mitchell: That doesn't affect what fumes and particulates come off of that. I'm going to share something now that's my opinion; BOFA hasn't taken a position one way or the other on this, so I want to say it as my opinion and not BOFA's. My background is in the soldering industry. I was in that for a long time, and I have always heard people talk about they're worried about the fumes containing some metal. All of the studies I ever had seen conclude that isn't the case. The fumes are the flux. There's potential, theoretically, that some molecule of the solder could grab on to that flux particle that's being vaporized and you'd get a little bit of that. I haven't seen a study that said that's happening. All of that's to say that the size of the sphere of solder that's used in a solder ball I don't see it having much of an effect on what we're picking up.

What has a much greater effect is all of the changes in the chemistry and the types of fluxes. Going to the no-clean flux, you have a lot smaller percentage of solids in that, which are what end up in a lot of that vapor that's caused by it. Because we're going to lead-free solders, they melt at a little higher temperature, and industry has kind of typically then said, "Everything needs to be done hotter," which then causes a little bit more vaporization of that flux material. Or in a lot of hand soldering applications, you get people adding liquid flux to their flux-cored solder that kind of starts counteracting the no-clean that they were using. If you throw enough no-clean flux on something, you're going to need to clean it.

AD 1000 iQ laser fume extraction system shown with access door open.

Johnson: Does that increase the filtration need, and do you have to go to different filters or move more cubic feet per minute?

Mitchell: It would still be the same types of filters. I would not say that it requires additional airflow, it doesn't require a different filter set. It requires the attention to creating that capture area.

Johnson: When you go into a customer facility to talk to them about fume capture, how often do you find that the facility is adequately arranged? As far as the physics of setting up

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their shop, do you find most facilities are adequate or is there room for improvement?

Mitchell: From the standpoint of capturing and filtering and reintroducing the air into the room, I'd say we see a lot of room for improvement with that. Our biggest competitor is still blowing the air out of the building onto your neighbors.

Johnson: That can't be great for the environmental sorts of guidelines that are coming up.

Mitchell: Right. Especially in the electronic industry, the majority of the large ovens and conformal coating systems, and all of that is being vented out of the building. Hand soldering, I'd say a significant amount of that is being run through some type of a filter, a local exhaust filter, and part of that's because all of the soldering iron manufacturers realized years ago that there was a great accessory they could be selling with their iron, which was some type of a capture system.

A number of companies manufacture a fume extraction capture system that they sell with their irons. They all work on essentially roughly the same process: the pre-filter, some type of a higher efficiency filter, possibly a HEPA. To remove odors/gas, some of them include a foam pad that's impregnated with carbon; that doesn't capture odors for very long. Some of them have activated carbon in them.

Johnson: There are a variety of levels and capabilities that are available.

Mitchell: Right.

Johnson: Your region includes the U.S. states California, Oregon, and Washington. These three states are known for being pretty aggressive in their environmental protection legislation. What are some of the legislative or environmental protection challenges that your customers in these three states are dealing with on a regular basis?

Mitchell: I would say they have more of a challenge with, or maybe more questions about, how to dispose of the filters once they've reached their end of life than they do about the necessity of using fume extraction. There seems to be less regulation on the environment that the operator works in than the disposal side of the industry.

Johnson: What are those challenges?

Mitchell: The basic questions that I get are, "Can I dispose of the filter, and if so, how?" My answer is when my filter is new, it doesn't have anything in it that requires any type of special handling for disposal. It's a stainless steel case with a glass paper filter, and activated carbon, which can be disposed of through any normal process. But once you start pulling in material to it, what I typically tell them is every municipality is going to have its own requirements. The best advice I can give to people is you want to treat that filter the same way you would treat the material you were processing that the filter has now absorbed or adsorbed, depending on what you were doing. Then, every time you change zip codes, your requirements could change a little bit.

Johnson: I have a filter I swapped out, and now I have to dispose of it. Perhaps this filter has come out of the hood over the laser router, and has collected material that is not safe for the general landfill. What do I do?

Mitchell: Probably the easiest way to say it is you'd be disposing of it the same way you dispose of any leftover material. It's going to go through the normal process of disposing of material; which may indeed be your local landfill.

Johnson: The waste management chain that you already have in place, then?

Mitchell: Right. And then if you are working with some material that was a little bit more exotic, you're going to have that same chain for that type of material. It might go through an incinerator process or something like that, but the easiest way to describe it is you're

not going to have to do anything differently because it's a filter, it has to be however you would have processed that material.

Johnson: Is it fair to assume that if a company is working with that material already that they've also set up an appropriate channel for disposal? Then they would use the same channel?

Mitchell: Right. I'm not adding complexity to that because that system would have already existed for what they were working with.

Johnson: What do you currently see as the biggest challenges for electronics manufacturers in managing fume extraction and the breathable air quality in their work environment?

Mitchell: I guess I would say the cost justification of filtering the air versus throwing it outside.

Johnson: Right. You have some major competitors that toss it outside, and if that's good enough, then that's good enough.

Mitchell: It's "good enough as long as nobody complains," they say. And then, once somebody complains, they start looking at alternatives. There are cost justifications; you have to dig a little deeper sometimes to find those, though. Take the example of manufacturing in Arizona. During blistering hot summers, you're spending all this money to get the air temperature down in your facility to a manageable level where people are comfortable, and then you have a bunch of holes in your ceiling where you're pouring that conditioned air out of the building with fans helping to pull it out of the building. Now, I have to pull new air into the building, re-cool it, and send it back out to the building. Where if you hook this up to a local exhaust ventilator, you're not throwing the air out of the building; you're going to pull it through these filters and exhaust it back into the building.

Johnson: It's the same thing for preserving the heat inside for the colder climates, too.

BOFA's V250 Fume & Dust Extraction System.

Mitchell: Exactly. That's a more difficult calculation to make of how much that's costing you. Maybe less obvious would be the way to say it. Another advantage you have with local exhaust ventilation is—especially with electronics manufacturing—when you put a plant together and run it for six months, and then your product mix or volume changes, you're like, "I wish I had realigned or moved this line differently and had this oven over on a different side of the building, or even 30 feet away from where it is now." If you're venting out of the building, you're calling the HVAC company, and they have to come and run a new line, or possibly even punch a new hole in the ceiling or a wall. If you run local exhaust ventilation, you unplug it from the wall, you roll it to where you want it now, and you plug it back into the wall for power.

Johnson: Do any of your products have sensors to monitor what's in the air or any metrics about the air quality going into the air filters?

Mitchell: No, there's not a before and after. There's a sensor you can add into the exhaust

The BOFA 3D PrintPRO 2 extracts fumes generated by the printer without causing the filament deposition area to be cooled.

that's looking for VOCs to let you know when it's time to change the carbon. As the glass paper filters capture particulate, they start to restrict the airflow, so there are sensors built into it that are able to tell you as the filter's getting full when it's time to change that filter. As carbon gets saturated, it doesn't change the airflow; it works like a sponge. You fill up a sponge with water, and if you pour more water into the sponge, it passes through. That's what will happen with carbon eventually, so you can add a sensor into the exhaust that's looking for a certain level of VOC to say, "It's time to change it." Of course, a lot of people also use their nose. Some VOCs have more odor, and your nose tells you right away when it's passing through; they'll change it then.

Johnson: Any parting comments within the context of fume extraction, fume management, and the current state of the art in soldering?

Mitchell: What we try to do with this equipment is to create not just a safe environment, but also a productive environment, less downtime with the equipment, less downtime with your operators, and using the filtering capability allows you to do that.

Johnson: That's a pretty good claim. How does that help with the downtime?

Mitchell: The particulates and fumes that are generated—such as with lasers—if you're not getting the fumes and smoke pulled away adequately from the laser, it's going to start to cause problems with your optics, which is going to cause more downtime as you have to stop to clean the optics every X number of hours. This is going to greatly extend that amount of time. Operators hand soldering with the potential for breathing, sinus issues, occupational asthma, and those types things—there will be less downtime for your operators if you're properly removing the fumes and odors from their work environment. Working with routers and those types of things for removing boards, you have a lot of debris. Again, if you're pulling that away from the equipment, but the equipment is able to go longer without requiring the maintenance of cleaning all that material out.

Where it's taking off is both on the consumer side of it and even in the manufacturing industry side of it. The 3D printing industry is becoming quite an industry, both from the consumer hobbyist, such as people who have a little 3D printer at their home to companies that are making every kind of part you could ever imagine with 3D printing—they're now 3D printing with both plastic and metal materials.

We find that's sort of the industry where there's a lot of education taking place now of the need for fume extraction. We see a lot of schools and universities realizing this—even elementary schools. You're essentially heating up that plastic and liquefying it. It depends on which material you use and all of that, but some things would be better not to be breathed in; they are starting to look at the different ways to filter that so that you don't contaminate your environment.

Johnson: That's a good point because 3D printing technology is appearing in the electronics manufacturing sector much more readily.

Mitchell: Exactly.

Johnson: Thanks, Andy. **SMT007**


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Developing a Reflow Profile

SMT Solver
Feature Column by Ray Prasad, RAY PRASAD CONSULTANCY GROUP

Developing a reflow profile for electronic assemblies is like trying to figure out the time and temperature (bake profile) to bake turkey, chicken, and shrimp for the same length of time at the same temperature in the same oven without undercooking the turkey or overcooking the shrimp. The difference, however, is that using a bad reflow profile for electronic products is much more consequential than an undercooked turkey or overcooked shrimp and some disappointed guests you invited for dinner.

The basic idea of developing a good profile is to make sure all solder joints reach the minimum temperature to achieve good solder joints but don't exceed maximum temperature to prevent damage to components or to solder joints. This is not an easy task, especially when you have a board with components of different sizes and thermal masses: BGAs, sockets, fine-pitch, BTCs, and 0402/0201, similar to the previous example.

The good news is that we have the tools, technologies, and processes to deal with the profiling challenge. What I plan to do in this and a few follow-up columns is to provide specific guidelines and rules for developing a unique profile for each product without any damage and warpage to components and boards and with minimum possible profile-related defects. More specifically, I will try to:

a. Provide an overview of various types of thermal profiles, purpose, key requirements, and challenges in developing thermal profiles.
b. Explain the importance of different soldering zones—such as preheat, soak, reflow, and cooling—and their impact on solder quality.
c. Discuss the details of how and where to attach thermocouples to achieve the desired soldering temperatures in various soldering zones.

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d. Emphasize the importance and difference between time above liquidus (TAL) and true TAL and their impact on the quality of solder joints, especially on head-on-pillow.
e. Provide specific recommendations for thermal profiles for most commonly used Pb-free (SAC and low-temp), Sn-Pb, and mixed alloys.
f. Discuss conflicting requirements of different types of packages and alloys on the same board and show some examples of profile related defects.

What Is a Thermal Profile?

A thermal profile is a unique temperature vs. time plot for each fully populated printed wiring board assembly (PWBA) using thermocouples attached to the solder joints with high-temperature solder, copper, or aluminum tapes to selected representative components on the board as the board travels at a given belt speed through various temperature zones of an oven or soldering system. There is a lot in that one sentence, but it is worth paying attention to some of the things I mentioned.

For example, you need to use a fully populated board and definitely not a bare board or another board that possibly looks like the board but a fully populated board that comes as close as possible to the thermal mass of the product you are profiling. You are using thermocouples that are attached with high-temperature solder or copper or aluminum tapes and not Kapton tapes used by many people. The location of attachment is generally the solder joint itself (unless you're specifically monitoring other spots, such as temperature-sensitive body components or the bare board itself, when using low-Tg PCBs.) And even the length (about a meter) of the thermocouple wires and their gauges (about 36 gauge) is very important so that you don't get the incorrect temperature.

And you need a unique profile for each product. One profile will not work for all products, even if they tend to look alike. The reason is simple. Each PWBA has a unique thermal mass. Different boards have varying thermal mass because they have a various number of layers, and the number and location of ground and power planes may be different, and they certainly have different types of components. Even the same board will need two profiles if it has components on both sides. For example, a single-sided board will need different temperature and belt speed settings than the same board loaded with components on both sides. Think of a single-sided board as a chicken and the double-sided heavier board as a turkey. Chicken and turkey require very different thermal profiles to prevent overcooking or undercooking. PWAs are no different.

What Is a Misleading Profile?

Profiles not correctly developed are misleading profiles. For example, profiles using bare boards will give you a misleading profile. You must use a fully loaded board. Profiles using rejected bare PCBs and dummy components or pennies that simulate the thermal mass of actual components is a good place to start if real boards and components are not available or affordable.

Profiles not correctly developed are misleading profiles. For example, profiles using bare boards will give you a misleading profile.

Profiles using Kapton tapes to attach thermocouples will give you wrong temperatures, especially since they tend to come off during the profiling process. You must attach TCs using high-temperature solder or copper or aluminum tapes. Thermocouples attached to the PCB surface and not attached to solder joints will give you a misleading profile. It is important to keep in mind that developing the thermal profile is a destructive operation but

needs to be performed only once during the entire life of that product.

Developing a profile is like using correct DFM. You have to do it only once (DFM and profile development). But it is amazing to hear how the process engineers complain about DFM but don't take the time, barely an hour, to develop a unique profile for each product.

Purpose and Types of Thermal Profiles

What is the reason for developing a unique profile for each product? There is only one purpose for using the correct profile: to reduce defects and to produce acceptable electronic assemblies. Yes, there are many causes of defects, and the right profile is not the panacea for solving all defects. Nothing is because there are many causes of defects in an electronic assembly, but the thermal profile plays a leading role. It is the simplest thing to take care of, but many people don't take the time. There are many ways to develop a thermal profile, but there is only one way to correctly develop the thermal profile, which I mentioned earlier.

There are two types of profiles: ramp to peak (RP) and ramp to soak to peak (RSP). The key difference between an RSP and an RP profile is the absence of the soak zone in the RP profile. An RSP profile allows a more uniform temperature across the PWBA, and it is very useful in achieving uniform temperature in a PWBA with a large variation in thermal masses of different components. RSP profiles also make it easier to achieve lower voids in solder joints, especially in BGAs.

RP profiles may increase the incidence of voids in solder joints, but they minimize the incidence of head-on-pillow in BGAs, which is a serious defect. Here is what you need to keep in mind. The presence of voids is not a serious concern for product reliability, but head-on-pillow is an open causing a board to be nonfunctional; so it very simple. If there are BGAs on your board, worry about head-on-pillow and not voids. There are many causes of head-on-pillow—a topic that would take more than one column to discuss—but at least using the right profile is the easiest thing to take care of.

Zones in a Profile

There are only two things we control in developing a profile: belt speed and temperature settings in each zone. Further, there are four zones in any profile: preheat, soak, reflow, and cooling. Here is a brief summary of each zone.

1. Preheat Zone

The temperature in the preheat zone can be from 30–175°C. Component suppliers recommend 2–4°C per second ramp rate to avoid thermal shock to sensitive components. Such guidelines are considered conservative since some capacitors are wave soldered and go from a preheat temperature of nearly 120°C to a wave pot temperature of 260°C. A high ramp rate increases the potential for solder balls, so keep it as low as feasible with consideration for the recommended ramp rate for the temperature-sensitive components on the board.

2. Soak Zone

The soak zone is intended to raise the temperature of the entire PWBA to a uniform temperature. The recommended ramp rate in soak zone: 100–180°C for Sn-Pb and 140–220°C for SAC. The soak zone also acts as the flux activation zone for solder paste. The consequences of having too high a temperature in the soak zone can include solder balls, solder splatter due to excessive oxidation of paste, and spent flux activation capability (burnt-out flux that fails to scrub the oxidized surface, its main function). Also, the purpose of a long soak zone is to minimize voids, especially in BGAs and BTCs.

As mentioned previously, it is also common practice to not use a soak zone but to steadily ramp the temperature from the preheat zone to peak reflow. The likelihood of voids may increase when ramping steadily (RP profile) to peak reflow temperature.

3. Reflow Zone

The peak temperature in the reflow zone should be high enough to obtain good wetting and to create a strong metallurgical bond. However, the temperature should not be so high as

to cause the component or PWBA damage or discoloration or, in the worst case, delamination or charring of the PWBA. On the other hand, a temperature that is too low may result in cold and grainy solder joints, non-melted solder, or poor intermetallic bonding. As a general rule of thumb, a higher peak is preferable to a lower peak temperature to prevent opens/non-wetting.

The recommended peak temperature in reflow zone is between 210–220°C (absolute minimum of 205°C) for SnPb and 235–245°C (absolute minimum of 230°C) for Pb-free solder alloy. The TAL should be 60–90 seconds but closer to 60 seconds. Extended duration above the solder melting point, or TAL, will damage temperature-sensitive components. It also will result in excessive intermetallic growth, which makes the solder joint brittle and reduces solder joint fatigue resistance.

4. Cooling Zone

During the cooling zone, various materials will cool at different rates. The BGA package typically will cool faster than the BGA solder joints and much faster than the bare board. This differential cooling can create a mechanical strain on the weakest spot in the interconnection, which is the laminate below the BGA pad, potentially resulting in pad cratering.

A faster cooling rate decreases the grain size, improves the joint strength, but increases the warpage and the potential for pad cratering. Pad cratering defects have become more common due to the increased stiffness of SAC solders and Pb-free laminates. Pad cratering depends not only on cooling rate but many other factors, such as stiffer lead-free solder and stiffer Pb-free laminate. As a practical matter, in most ovens, turning the cooling fan on and off are the only options for controlling the cooling rate unless the cooling zone has an option for blowing cold air.

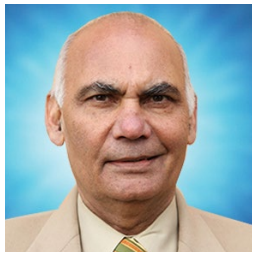
Challenges in Developing Thermal Profiles

There are many challenges in developing a profile. For example, all solder joints must reach the minimum soldering temperature (15–20°C above liquidus) to allow wetting of the solder surfaces and the formation of intermetallic but also not exceed a maximum peak to prevent damage. However, there are components of different thermal mass (socket, BGA, chip components, etc.) that require different thermal input. A minimum soldering temperature is essentially determined by the largest component, such as a BGA, but the maximum is determined by smaller and temperature-sensitive components.

Even though different products, based on their thermal mass, require different amounts of thermal input, all products must achieve the minimum temperature (temperature above liquidus) without exceeding the maximum temperature (without damage to any components) within a defined time period (thermal profile). This is the key reason for developing a unique profile for each product. Developing a good profile is a balancing act to ensure intermetallic formation in heavier components without causing dewetting in smaller components due to overheating.

Future Columns

In future columns, I will take on some of the other key points in reflow profile development that I mentioned in the beginning. **SMT007**



Ray Prasad is the president of Ray Prasad Consultancy Group and author of the textbook Surface Mount Technology: Principles and Practice. Prasad is also an inductee to the IPC Hall of Fame–the highest honor in the electronics industry–and has decades of experience in all areas of SMT, including his leadership roles implementing SMT at Boeing and Intel; helping OEM and EMS clients across the globe set up strong, internal, self-sustaining SMT infrastructure; and teaching on-site, in-depth SMT classes. He can be reached at smtsolver@rayprasasd.com and has an upcoming SMT class in July (remotely by Zoom). More details at www.rayprasad.com. To read past columns or contact Prasad, click here.

MilAero007 Highlights

What It Takes to Be a Milaero Supplier, Part 2 ▶

The decision to pursue military and aerospace certification impacts every facet of the organization, and not every shop is prepared to make this transformation. In Part 2, Anaya Vardya focuses on what it takes to be a milaero supplier in the areas of engineering and CAM.

Defense Speak Interpreted: Be Prepared for CMMC ▶

If you are a current or future Defense Department contractor or subcontractor, you need to be prepared for the next cybersecurity requirements coming online during 2020. This is the Cybersecurity Maturity Model Certification, or CMMC, in Defense speak. Dennis Fritz explains how there will be five levels of cybersecurity requirements for various amounts of Controlled Unclassified Information you handle, with increasing requirements from one (least) to five (most).

U.S. Army Awards $339 Million Contract for M109A7 Self-propelled Howitzers ▶

The U.S. Army has awarded BAE Systems a $339 million contract modification for the production of 48 vehicle sets of M109A7 Self-propelled Howitzer (SPH) and its companion, the M992A3 Carrier, Ammunition, Tracked (CAT) vehicle, and includes post-delivery support and spare parts.

Astro Aerospace Adds Med-evac Pod to the Fleet ▶

Astro Aerospace—the company creating autonomous, eVTOL (Electric Vertical Takeoff and Landing) aerial vehicles and drones—has added another new model to its ALTA platform line-up in the form of a med-evac/ambulance vehicle.

ControlTek Inc., Critical Manufacturer of Medical and Aerospace and Defense Products, Will Maintain Operations ▶

Electronics manufacturer ControlTek Inc. announced its Vancouver, Washington, manufacturing facility will remain open while implementing additional safety measures to maintain production support for critical manufacturing sectors, including medical and military.

Lone Star Circuits Inc. Recognized by Raytheon With 4-star Honors ▶

Lone Star Circuits Inc. was one of 86 companies recognized by Raytheon's Integrated Defense Systems business for 4-star honors.

Lockheed Martin Chairman, President and CEO Marillyn Hewson On COVID-19 Response ▶

At Lockheed Martin, we recognize that the rapid spread of COVID-19 and its wide-ranging impacts have caused severe disruption across society and the tragic loss of life around the world. We also recognize that the global pandemic has created a need for urgent action by governments, businesses, communities, and citizens.

U.S. Air Force Awards Lockheed Martin Avionics Tech Refresh Contract to Advance U-2's Capabilities for the Future Battlespace ▶

Lockheed Martin Skunk Works® continues to evolve the U-2 Dragon Lady to support future battlespace needs under a recent contract award from the U.S. Air Force valued at $50 million. The contract underpins U-2's role in bridging capabilities needed for the next generation.

Getting to the Root Cause of BGA Assembly Problems

Knocking Down the Bone Pile

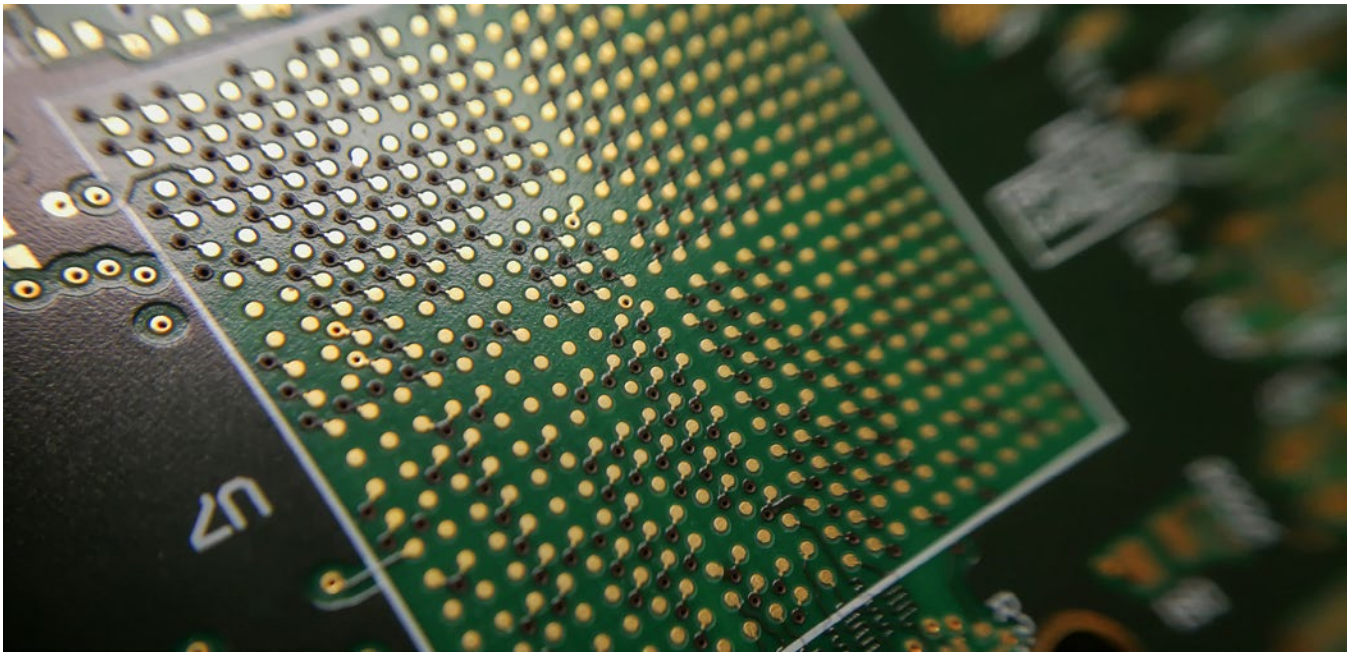
by Bob Wettermann, BEST INC.

When potential process defects begin showing up underneath BGAs in electronic assemblies, there are numerous failure analysis tests that can be used to troubleshoot process problems. These investigative methods begin with non-destructive test methods and progress to destructive methods as some of the possible root causes are eliminated.

After electrical testing has been performed, there are numerous inspection methodologies spelled out in the IPC-A-610 [1] to use in determining potential assembly defects at BGA locations. These inspection methodologies include visual inspection via a microscope and borescope, as well as X-ray analysis. The first level of BGA failure analysis is visual inspection with the aid of a microscope or borescope. Visual inspection criteria per the IPC A-610 can be found in the SMT portion of the IPC-A-610.

In most cases, BGAs are inspected to see the uniformity of collapse along the outer row of the package, with special attention being paid to the corner locations. This can be done when the view is unobstructed via a microscope. The magnification and lighting will be crucial to seeing the outside row of the BGAs. As long as the flux residue has been cleaned and the conformal coating is not obstructing the viewing area, criteria—such as the uniformity of the ball collapse, the distance between balls, and the distance from balls to any neighboring ungrounded surface—can be seen using visual inspection.

The next level of visual inspection, which may, in some cases, allow for inspection into the third row of the area array device, will be via a borescope. A borescope, borrowed from the medical industry, allows for images



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to be captured a few rows into the package. This visual inspection tool is especially useful when neighboring components are only a few millimeters from the perimeter of the BGA. Both direct and indirect lighting methods can provide the necessary illumination to capture meaningful solder ball images. The quality of the images obtained depends on the quality of the light, the mirrors used on the end of the endoscope, the lenses, and the quality of the light going to the imaging area. In addition to these visual techniques, X-ray imaging will also help to diagnose and troubleshoot the process being investigated.

Transmissive X-ray imaging is a widely-used non-destructive imaging tool that allows for all of the solder and solder balls to be seen underneath the BGA package. There are numerous anomalies and defects that can be seen through the use of X-ray inspection. X-ray inspection of the entire device field using a wide field of view generally is the beginning point of the BGA X-ray inspection process. This is followed by closer, higher magnification inspection of "areas of interest."

Shorts and violations of minimum electrical clearance are common problems which can be measured and found using X-ray inspection. More subtle defects also show up on X-ray inspection, such as incomplete or inadequate wetting or head-in-pillow non-coalescing solder joints. Furthermore, measurements of the solder ball diameters and collapse height as well as sphericity, void percentage, and other attributes can be determined via careful X-ray inspection using higher-end X-ray equipment. Destructive testing could augment both the visual and X-ray inspection methods for

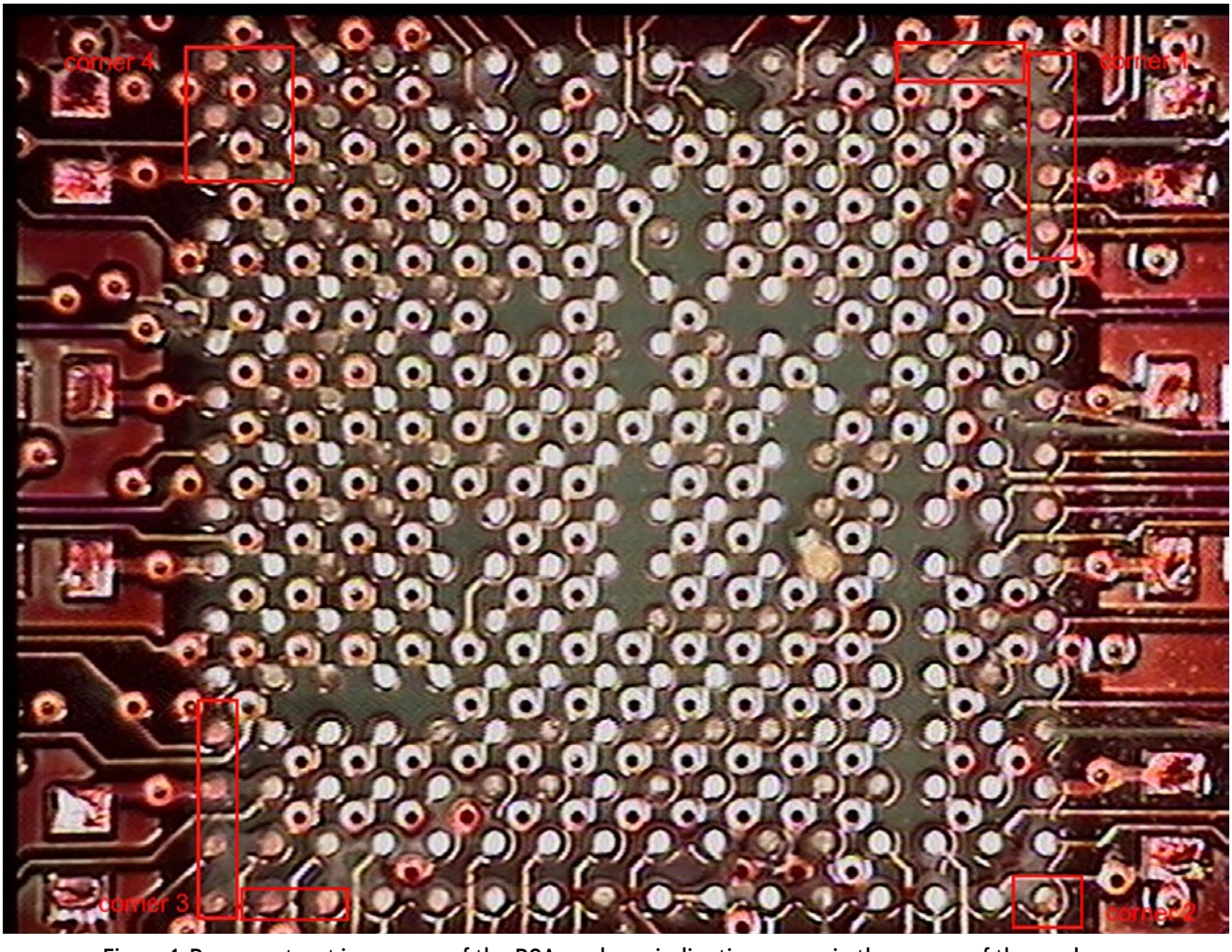


Figure 1: Dye penetrant in corners of the BGA package indicating opens in the corner of the package.

"no specific defects noted" conditions during either inspection process.

Dye and pry testing [2] is a relatively simple, cost-effective destructive method for testing the integrity of the solder joint on a BGA package. The method does not require any high-end capital equipment instead of relying on generally available investigative or production tools, such as a small vacuum chamber, a bake-out oven, a pry tool, and a microscope. Testing of this type can be outsourced to failure analysis test labs or be done by the user.

The first step is determining the test location. Dye penetrant is squirted underneath the package at the location of interest. Make sure the dye has made its way underneath the suspect device. Place the package in a vacuum chamber to make sure the penetrant flows into cracks in the solder joint or cracks in the pads. Cure the penetrant in a bake-out oven per the dye penetrant manufacturer's recommendation so as to not smear the dye around the package for a false positive reading due to smearing.

Once the dye is dried and cleaned, the BGA is pried from the board. Areas in and around the ball interface are examined (Figure 1) to see where the dye may indicate an open connection. The dye penetrant left behind at the solder interface will indicate failures such as pad cratering and solder joint fractures from thermal, mechanical, or drop shock. If no failures are indicated by the dye, then other test methods—such as cross-sectioning, acoustic microscopy, and EDX or SEM analysis—may be the next steps in finding a root cause in the BGA solder joint failure analysis. **SMT007**

References

1. IPC-A-610 Acceptability of Electronic Assemblies, section 8.3.12.
2. IPC-TM-650 Method 2.4.53 Dye and Pull Test Method.

Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago. For more information, contact info@solder.net. To read past columns or contact Wettermann, click here.

Learning About Artificial Intelligence: A Hub of MIT Resources for K–12 Students

In light of the recent events surrounding COVID-19, learning for grades K-12 looks very different than it did a month ago. Parents and educators may be feeling overwhelmed about turning their homes into classrooms.

With that in mind, a team led by Media Lab Associate Professor Cynthia Breazeal has launched aieducation.mit.edu to share a variety of online activities for K-12 students to learn about artificial intelligence, with a focus on how to design and use it responsibly. Learning resources provided on this website can help to address the needs of the millions of children, parents, and educators worldwide who are staying at home due to school closures caused by COVID-19, and are looking for free educational activities that support project-based STEM learning in an exciting and innovative area.

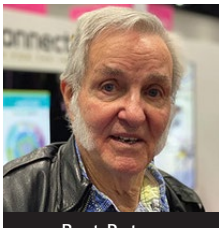
The website is a collaboration between the Media Lab, MIT Stephen A. Schwarzman College of Computing, and MIT Open Learning, serving as a hub to highlight diverse work by faculty, staff, and students across the MIT community at the intersection of AI, learning, and education.

The site is intended for use by students, parents, teachers, and lifelong learners alike, with resources for children and adults at all learning levels, and with varying levels of comfort with technology, for a range of artificial intelligence topics.

(Source: MIT)

Editor's Picks from SMT007.com

1 Exclusive Interview With Burt Rutan, Aerospace Legend ▶


Burt Rutan

If you follow advancements in aerospace technologies and expeditions, then you know the name Burt Rutan. Described by Newsweek as "the man responsible for more innovations in modern aviation than any living engineer," Rutan is a bold visionary with a passion for the advancement of technology, who has designed 46 aircraft throughout his career.

2 Powerful Prototypes: Manufacturing in an Uncertain World ▶

In the best of times, electronics manufacturing is an exercise in taking chaos (in the form of data and information of multiple non-aligned forms and formats) and creating order (in the form of a working PCB). Duane Benson shares four things you can do to better ensure that your projects can be built and improve your habits.

3 Foundations of the Future: The Substantial Growth of IPC Student Chapters ▶

The IPC Education Foundation launched the IPC Student Chapter Program in February 2019. The program aims to connect students in relevant two-year, four-year, and graduate programs to the electronics industry and IPC member companies. Aaron Birney provides an update on the substantial growth of IPC Student Chapters over the past year.

4 SMTA Europe's Electronics in Harsh Environments Conference and Exhibition: A Taste of Things to Come ▶


Pete Starkey

SMTA Europe's Electronics in Harsh Environments Conference has become a must-attend annual event; unfortunately, due to the COVID-19 lockdown, it has been postponed until December 1–3. Pete Starkey reports on a preview seminar presented by SMTA Europe.

5 Smart Factory Insights: Size Matters—The Digital Twin ▶


Michael Ford

In the electronics manufacturing space, at least, less is more. Michael Ford considers what the true digital twin is really all about—including the components, uses, and benefits—and emphasizes that it is not just an excuse to show some cool 3D graphics.

6 ICM Controls Remains Open in Support of Essential Services ▶

ICM Controls, a leader in the manufacture and supply of electronic controls, was classified as an essential service provider by NY State and granted exemption status; therefore, they are "not subject to the required 100% workforce reduction [mandate]" pursuant to the Governor's revised Executive Order 202.6.

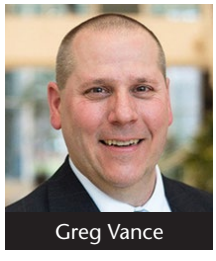
7 SMTA Releases Selective Soldering 101 Online Training Course ▶

The Surface Mount Technology Association (SMTA) announced the recent release of Selective Soldering 101, the latest in a series of online training courses on the fundamentals of electronics assembly.

8 Bosch Selects MIRTEC as Strategic 3D AOI Partner ▶

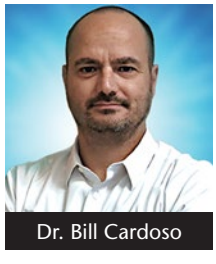
MIRTEC is pleased to announce that after an extensive evaluation, BOSCH has selected MIRTEC's 3D AOI Technology as the best solution to meet their ongoing quality initiatives.

9 Greg Vance to Serve as SMTA Interim President ▶


Greg Vance

Nolan Johnson talks to Greg Vance about taking over the SMTA Board President's role through September. This discussion includes an update on multiple board chair changes, and an update on the board's work to achieve their current set of objectives.

10 X-Rayted Inspection: Manufacturing in the Eye of a Pandemic ▶


Dr. Bill Cardoso

Dr. Bill Cardoso usually writes about X-ray inspection, artificial intelligence, machine learning, and how it all connects to Industry 4.0. This month, however, he shifts gears and shares some of the things Creative Electron has been doing during the COVID-19 outbreak.

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(Transcript also available.)

Roundtable Discussion


Teresa Rowe, IPC
Graham Naisbitt, Gen3
Jason Keeping, Celestica
Doug Pauls, Collins Aerospace

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Required: Bachelor's degree from a technical college/university in an associated field. Three years directly related experience, or equivalent combination of education and experience. Must possess a valid driver's license and have a clean driving record.

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- Experience using SKILL script automation such as dalTools
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- Self-motivated, with ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem solving skills
- Other design tool knowledge is considered a plus (Altium, PADS, Xpedition)

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Required Education and Experience:
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Thank you, and we look forward to hearing from you soon.

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- Provide product quality control and support
- Must comply with all OSHA and company workplace safety requirements at all times
- Participate in multifunctional teams

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- Minimum 4-year college degree in engineering or chemistry
- Preferred: 5-10 years of work experience in designing 3D and inkjet materials, radiation cured chemical technologies, and polymer science
- Knowledge of advanced materials and emerging technologies, including nanotechnologies

Working Conditions:

- Chemical laboratory environment
- Occasional weekend or overtime work
- Travel may be required

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Multiple Positions Available

The Indium Corporation believes that materials science changes the world. As leaders in the electronics assembly industry we are seeking thought leaders that are well-qualified to join our dynamic global team.

Indium Corporation offers a diverse range of career opportunities, including:

- Maintenance and skilled trades
- Engineering
- Marketing and sales
- Finance and accounting
- Machine operators and production
- Research and development
- Operations

For full job description and other immediate openings in a number of departments:

www.indium.com/jobs

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Career Opportunities

Manncorp™

SMT Field Technician
Huntingdon Valley, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

Duties and Responsibilities:
- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

Requirements and Qualifications:
- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

We Offer:
- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

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U.S. CIRCUIT

Sales Representatives (Specific Territories)

Escondido-based printed circuit fabricator U.S. Circuit is looking to hire sales representatives in the following territories:

- Florida
- Denver
- Washington
- Los Angeles

Experience:
- Candidates must have previous PCB sales experience.

Compensation:
- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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Career Opportunities

ZENTECH

Zentech Manufacturing: Hiring Multiple Positions

Are you looking to excel in your career and grow professionally in a thriving business? Zentech, established in Baltimore, Maryland, in 1998, has proven to be one of the premier electronics contract manufacturers in the U.S.

Zentech is rapidly growing and seeking to add Manufacturing Engineers, Program Managers, and Sr. Test Technicians. Offering an excellent benefit package including health/dental insurance and an employer-matched 401k program, Zentech holds the ultimate set of certifications relating to the manufacture of mission-critical printed circuit card assemblies, including: ISO:9001, AS9100, DD2345, and ISO 13485.

Zentech is an IPC Trusted Source QML and ITAR registered. U.S. citizens only need apply.

Please email resume below.

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BLACKFOX
Premier Training & Certification

IPC Master Instructor

This position is responsible for IPC and skill-based instruction and certification at the training center as well as training events as assigned by company's sales/operations VP. This position may be part-time, full-time, and/or an independent contractor, depending upon the demand and the individual's situation. Must have the ability to work with little or no supervision and make appropriate and professional decisions. Candidate must have the ability to collaborate with the client managers to continually enhance the training program. Position is responsible for validating the program value and its overall success. Candidate will be trained/certified and recognized by IPC as a Master Instructor. Position requires the input and management of the training records. Will require some travel to client's facilities and other training centers.

For more information, click below.

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Professionals Seeking Employment

db MANAGEMENT GROUP
Strategic Business Growth Consultants

D.B. Management Group L.L.C. is currently working with many professionals who are seeking new positions. If any of these qualified professionals sounds like someone you would like to learn more about, contact **Dan Beaulieu** at **207-649-0879** or **danbbeaulieu@aol.com.** If you are a qualified professional looking for a new opportunity, contact Dan as well. Fees are 10% of candidates' first year's annual compensation. There is no fee for candidates.

Click here to contact Dan Beaulieu ▶

President, Company Leader, Business Builder
This professional has done it all. Built new businesses and turned around hurting businesses and made them successful. A proven record of success. This candidate is a game-changer for any company. He is seeking a full-time leadership position in a PCB or PCBA company.

General Manager PCB and PCBA
Senior manager with experience in operations and sales. He has overseen a number of successful operations in Canada. Very strong candidate and has experience in all aspects of PCB operations. He is looking for a new full-time position in Canada.

Regional Sales Manager/Business Development
Strong relationship management skills. Sales experience focused on defense-aerospace, medical, high-tech PCB sales. Specializes in technical sales. Also has experience in quality, engineering, and manufacturing of PCBs. He is looking for a fulltime position in the Southeastern U.S.

Field Application Engineer (FAE)
Has worked as a respected FAE in the U.S. for global companies. Specializes in working alongside sales teams. Large experience base within the interconnect industry. He is looking for a full-time position.

Business Development Manager
Understands all aspects of interconnect technical sales from PCB design and fabrication to assembly and all technologies from HDI microvias to flex and rigid-flex. Has also sold high-tech laminates and equipment. Proven record of sales success. He is looking for a full-time position.

CEO/President
Specializes in running multi-million dollar companies offering engineering, design, and manufacturing services. Proven leader. Supply chain manager. Expert at developing and implementing company strategy. Looking to lead a company into the future. He is looking for a full-time position.

PCB General Manager
Forty years of experience serving in all capacities, from GM to engineering manager to quality manager. Worked with both domestic and global companies. Available for turn-around or special engineering projects. He is looking for long-term project work.

Process Engineering Specialist
Strong history of new product introduction (NPI) manufacturing engineering experience: PCB/PCBA. Held numerous senior engineering management positions. Leads the industry in DFM/DFA and DFX (test) disciplines. He is looking for either a full-time position or project work.

VP Sales Global Printed Circuits
Worked with a very large, global company for a number of years. Built and managed international sales teams. Created sales strategies and communicated them to the team. One of the best sales leaders in our industry. He is looking for a full-time position.

Plant Manager
This professional has years of experience running PCBA companies. Led his companies with creative and innovative leaderships skills. Is a collaborative, hands-on leader. He is looking for a full-time position.

National Sales Manager
Seasoned professional has spent the past 20 years building and growing American sales teams for both global and domestic companies. Specializes in building and managing rep networks. He is looking for a full-time position.

Global Engineering Manager/Quality Manager
Has experience working with large, global PCB companies managing both engineering and quality staff. Very experienced in chemical controls. She is interested in working on a project-by-project basis.

CAM Operators and Front-end Engineers
These candidates want to work remotely from their home offices and are willing to do full-time or part-time projects.

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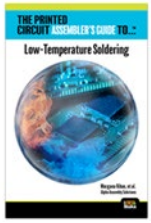
Advanced Manufacturing in the Digital Age, by Oren Manor, Director of Business Development, Valor Division for Mentor a Siemens Business
A must-read for anyone looking for a holistic, systematic approach to leverage new and emerging technologies. The benefits are clear: fewer machine failures, reduced scrap and downtime issues, and improved throughput and productivity.



Low-Temperature Soldering, by Morgana Ribas, Ph.D., et al., Alpha Assembly Solutions
Learn the benefits low-temperature alloys have to offer, such as reducing costs, creating more reliable solder joints, and overcoming design limitations with traditional alloys.

Conformal Coatings for Harsh Environments, by Phil Kinner, Electrolube
This handy eBook is a must-read for anyone in the electronics industry who wants a better understanding of conformal coatings. Kinner simplifies the many available material types and application methods and explains the advantages and disadvantages of each.

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COVER: **SHELLY STEIN**
COVER IMAGE:
ADOBE STOCK © ZOOM PHOTO & GRAPHICS

SMT007 MAGAZINE

SMT007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304

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May 2020, Volume 35, Number 5
SMT007 MAGAZINE is published monthly,
by BR Publishing, Inc.

ADVERTISER INDEX

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