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September 2014

the pcb magazine

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NEW CONCEPTS AND EMERGING TECHNOLOGIES

Aluminum Base Circuit Technology: Structures & Manufacturing Methods

by Joseph Fjelstad, page 18

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New Concepts and Emerging Technologies for PCB Fabrication

This month, industry experts from Verdant Electronics, LPKF, Optomec and Transline Technology explore up and coming technologies for PCB fabrication, layout and more.

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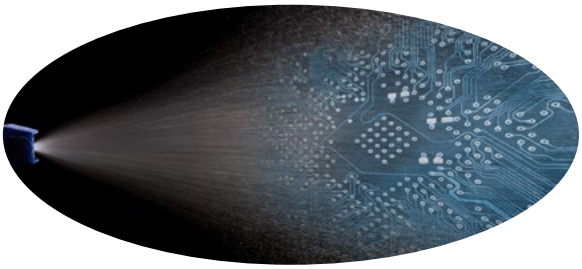

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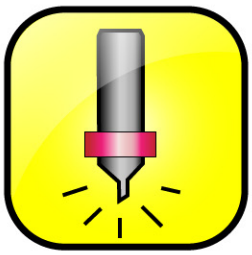

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NUMBER 9

THE DEFINITIVE
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Df @ 10 GHz	0.0030	0.0017	0.0031	0.0028 - 0.0036
CTE Z-axis (50 to 260°C)	2.90%	2.90%	2.80%	2.90%
T-260 & T-288	>60	>60	>60	>60
Halogen free	Yes	No	No	No
VLP-2 (2 micron Rz copper)	Standard	Standard	Available	Available
Stable Dk and Df over the temperature range	-55°C to +125°C	-40°C to +140°C	-55°C to +125°C	-55°C to +125°C
Optimized Global constructions for Pb-Free Assembly	Yes	Yes	Yes	Yes
Compatible with other Isola products for hybrid designs	Yes	Yes	Yes	For use in double-sided applications
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THE WAY I SEE IT

The Family (Sun)stone

by Ray Rasmussen
I-CONNECT007

During the IPC APEX EXPO show in Las Vegas, I had the chance to meet with Terry Heilman and Rocky Catt, owners of Sunstone Circuits. They wanted to introduce me to their new marketing manager, Matt Stevenson.

During the discussion, we talked about their company and what they believe is their unique style of doing business. Although I understood much of what they were trying to convey, Heilman suggested I make a trip to their factory to see for myself. I'd have to experience what they were doing to get the complete story. He was right. There was much more to the story.

By the way, the title for this article came to me early on while touring their factory and stuck in my head throughout the day and as I started to put this article together. I think you'll see why.

The Company

Sunstone Circuits is tucked neatly into a small valley in a rural community about an hour south of Portland, Oregon. Employing about 150 people, this nondescript factory, a kludge of rooms in a building constructed and modified many times over the last 50 years, pumps

Figure 1: Front row, l-r: Terry Heilman, Sheri Kuretich, Rocky Catt, Nolan Johnson, Nancy Viter. Back row, l-r: Molly O'Hara, Les Stephens, Paul Waterman, Matt Stevenson, Al Secchi.

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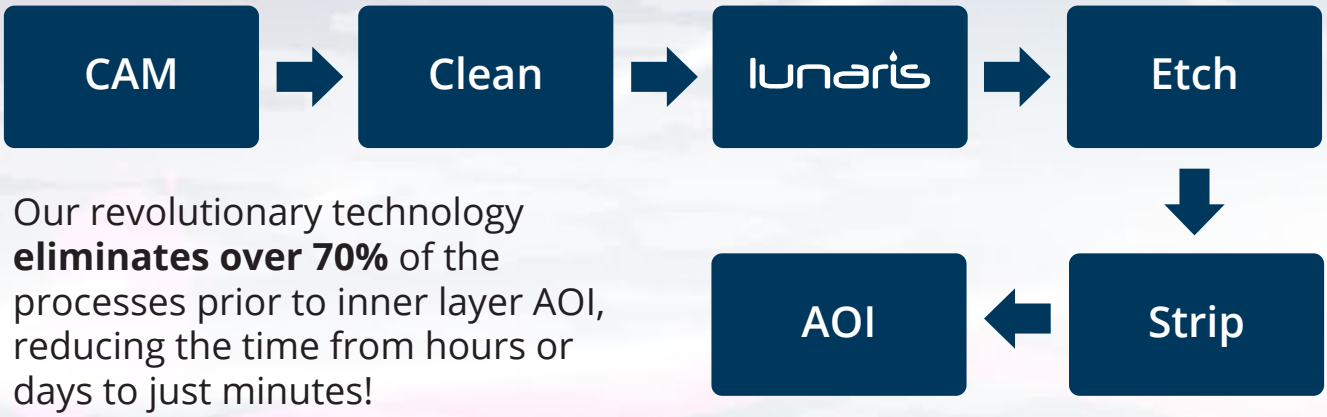

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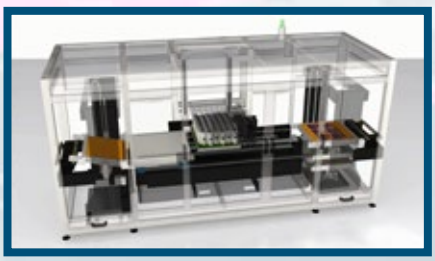

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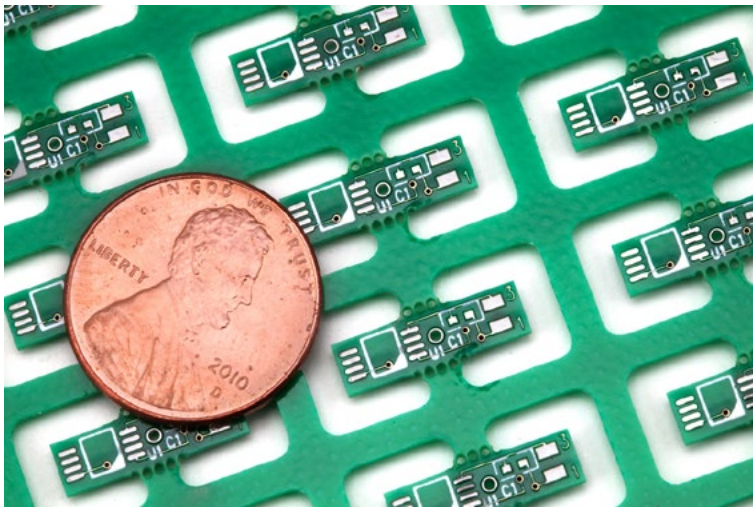
out about 200–250 quick-turn, prototype PCB orders each day to meet the needs of customers, predominately in the U.S. Like clockwork, orders flow into their highly automated website and frontend systems, and 24–72 hours later (mostly, depending on board configurations) flow out the back door of the shipping department.

Although a small manufacturing footprint, it's really easy to get turned around as you walk from room to room following a somewhat logical manufacturing flow. It's also easy to underestimate their capabilities. They do a lot with what they have to work with. The factory has had to grow up inside a less-than-desirable, seriously constrained environment. If asked, Sunstone managers will tell you that the company occupies 40,000 square feet, but that includes a brand new 8,000 square-foot office building which houses most of the management, customer service, inside sales, marketing and most admin functions. The rest is where they make PCBs, 24/7, almost 365 days of the year. It's not necessarily an elegant dance, but there is style, form, function and friendliness to it.

The Dance

Years ago I had the chance to visit high-tech proto maker DDi. At DDi, there wasn't any finesse. They muscled out high-tech protos to all comers at astronomical prices. It was a model that really worked for them. DDi had lots of technical capabilities and the people with the expertise to push the boards through the factory to capture the ridiculous amounts that Silicon Valley engineers were willing to pay to prove out a product design. As was pointed out to me, they were selling time, not just PCBs. I suggested to the management that some systems work might really help them lessen the chaos, accelerate the manufacturing flow and make more money. You had to admire what they did back then, but they could have done so much more and been so much better.

Sunstone is better. They don't tackle the technology the way DDi did, but they have certainly embraced systems thinking. Boards flow through the factory at lightning speed, but it's more of a dance as opposed to a monster truck rally. It's not a rushed or hectic environment,



but a nice, smooth flow. How often do you see harmony in a board shop?

The Family

Here's where I came up with the article title. During my span of 25 years covering the industry, I've heard lots of companies talk about their people in glowing terms: "we're like family," or "our people come first," or "it's all about the people." The majority of the time, those statements don't have much substance. You'll hear comments like that when a company embarks down some type of continuous improvement path. It's one of the first things managers start talking about, but it's also the first thing they drop when the going gets tough. With Sunstone, although they, too, have embarked on a continuous improvement path, the family (the people) genuinely does seem to come first. And I literally mean family: sons and daughters working with their parents who've been with the company for decades or spouses with long, collective histories with the company. Still, there is a company-wide esprit de corps fostered by the leadership. I'm sure it's not all roses, but there seems to be a genuine, top-down commitment to the well-being of the entire Sunstone family.

That commitment to the employees ultimately takes care of the customer. It's W. Edwards Deming's teachings without the Deming. Heilman and Catt say it just makes sense. It makes for a great place to work, builds employee loyalty and translates into a better expe-

rience for the customers. I heard that about a dozen times from their team of managers and from those working on the factory floor: "Does it benefit the customer?" was their mantra.

Almost Unique Sales Model

Sunstone has an interesting method of generating sales, which isn't entirely unique. Other companies follow a similar system but I doubt to this extent. The company markets heavily on the Internet, casting a wide net, moving prospective customers into the automated sales system built into their website. Orders are placed there and files are uploaded, and it's all done pretty much without human contact. According to Heilman, their goal is to bring in 15–20 new customer orders each working day. That's somewhere around 300–400 new customers each month, on top of the 4,000 or so orders they process from existing customers. To give you some perspective, with an average order value of around $500, you can work out some rough annual sales revenue numbers, which likely places them in the range of $20–30 million annual revenue. Having already attracted over 30,000 customers, I had to ask how many more prospects Sunstone thinks are out there. After all, it's a finite market. You can't reach 15–20 new customers a day forever. They felt comfortable with their strategy and thought that the goal could continue to be achieved for some time to come. Of course, they continue to nurture their current base of customers looking to grow that business, as well. My take is that they'll have to begin offering leading-edge technology capabilities to attract more business at some point.

Industry veteran Harvey Miller, owner of the PCB directory Fabfileonline, reports the size of the North American market to be about $1.2 billion for prototype PCBs annually. Heilman thinks that number is closer to $350 million for rigid board prototypes. In either case, Sunstone has room to grow.

The Sunstone model does sound attractive, though. They have a wide, diverse customer base (10,000 of the 30,000 placed orders over the last year), which builds in some security. Approximately 50% of Sunstone's customers provide about 75% of their revenue, which means they must do a great job of keeping customers; combined with the new ones coming in every day, it makes for good, predictable growth.

Another interesting fact about this sales model is that about 80% of their orders are paid by credit card, which partially explains why their bad debt only amounted to $3,000 over the last year. Other contributing factors are the various other benefits to their credit card model, such as increased cash flow, security of payment, etc. But there is a cost associated with this model, which does detract from the bottom-line benefit. Nonetheless, when you look at their cost of sales, cost of manufacturing, overhead, lack of debt service and, now, virtually no bad debt, they pick up a couple of points in all these areas. Overall it's a simple and effective model.

Customer is Always Right

This is easier said than done. At I-Connect007, we love our customers and tend to side with them when things go awry, but they aren't always right. Sunstone tends to walk the walk that no matter what happens, it needs to benefit the customer. I don't think this was a show put on just for my benefit. I heard it too many times, in too many places, from a lot of different people at Sunstone. They genuinely want to care for their customers. Everything they do must be of benefit to the customer. Again, Deming says it a little differently: Care first for employees, which Sunstone appears to do (see "The Family" above) and they will take care of the customer. Regardless of the order of things in Sunstone's thinking, it is what's happening: Everyone's needs are being met.

Philosophy

The owners claim that Sunstone is quite profitable, and they'll continue to work to drive waste out of their systems, which translates into additional profitability and more capacity, and in turn, increased benefits to customers. I get this, and I am quite surprised at how few companies pursue excellence in manufacturing and in business. It's a no-brainer for me.

Since 2005, when Heilman and Catt purchased the company from Electronic Controls Design (ECD), they've been able to pay off the previous owner and continue to upgrade capabilities while staying out of debt. Even the new

facility they built was paid for with cash. According to Heilman, being debt-free is by no means a mandate, but instead, a result of budgeting capital equipment and facility upgrades yearly in order to maintain a financially responsible model. That discipline has placed them in the catbird seat as they survey the industry for additional opportunities. They're certain that their business model will work in other PCB factories or in other industries, as well, and in turn, value the customer.

Alliances

Sunstone has a partnership with Screaming Circuits, an EMS partner that handles any assembly work that comes in. Located just 12 miles from Sunstone, Screaming Circuits, like Sunstone, is truly customer-focused, and their relationship is "very synergetic," says Heilman. When asked about vertically expanding their services, they were quite comfortable with their assembly partner as this point. While they do offer layout services for their customers, they are not in the design business.

The Technology

Sunstone does not pretend to build leading-edge PCBs, either; it's not their model. What they do is reliably deliver 2-, 4-, 6- or 8-layer, 5/5 mil lines and spaces boards, quickly, complete and on time, guaranteed. They can do up to 20 layers and tighter lines, but it's not their sweet spot. I do see a pretty compelling opportunity to climb the technology ladder a bit, which could open the door to more customers or significantly expand the volume of business they do with their current customers.

Their business model does not focus on performance certifications, and as such, they aren't certified for mil/aero or medical, but I did notice an ITAR registration from a 2012 press release. They say their customers just don't need those certifications to prove out a circuit, and that the amount of business they lose doesn't justify the expense of qualifying and maintaining the certifications—not for the kind of work they do.

Manufacturing Challenge

Running at about 75% capacity, there is room to grow, but the facility is currently maxed in size due to land zoning restrictions. That size restriction is somewhat limiting and is requiring them to look at new equipment which can produce more product within the existing footprint. The good news is that many of the new systems do just that. And, as long as they're as profitable as they say they are, buying the equipment necessary to add another 20–50% capacity is very doable. In addition, just about everything they buy will give Sunstone higher-tech capabilities, which could help them move up in technology offerings.

Small Batches

Optimized processes designed to utilize equipment efficiently translates into five or six 14"x16" panels making up the normal lot size running through the factory. Because of that, you see equipment sized to fit that manufacturing model. Panel utilization is maximized as like jobs are aggregated or nested with other like boards, while increasing throughput to keep costs down for the customer. I do believe Sunstone has an opportunity to accelerate their manufacturing even more, but that would probably require additional equipment and more factory floor space. But right now, if customers order a conforming PCB by 4 p.m. PST, they can be assured that their order will ship the next afternoon.

In their shipping department, a five-foot high stack of FedEx and UPS boxes are staged and ready to meet the day's orders. What looks like a frenzy really isn't one at all. It's a well-oiled machine driven by tight systems and highly dedicated employees, although the department tends to get a bit harried as shipping times approach, I was told. But most jobs fit nicely in the shipping boxes provided, which simplifies and speeds up the shipping process.

Redundancy

Quite honestly, redundancy was the weak link for me. Because of their factory size constraints, they aren't able to add a lot of redundancy to their systems. Also, their location, although it's probably a great place to live, is somewhat isolated. However, according to Heilman, that's where the years of experience come in. And as Nancy Viter, director of manufacturing explained, when their photo processor

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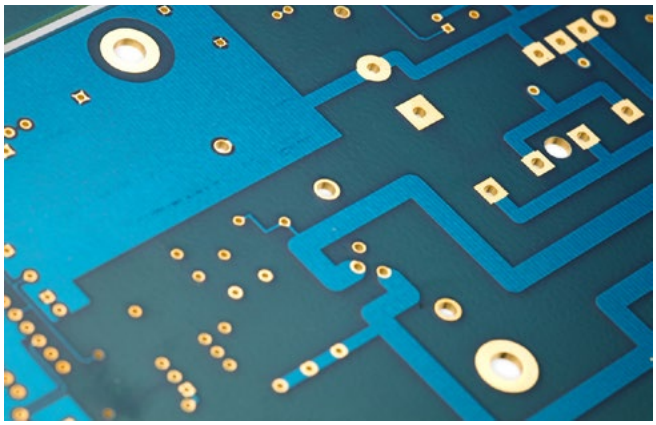

went down recently, instead of panicking, they switched back to trays of solution to process the film, the way they used to do it. They do the same when other processes fail. They know how it was done in the old days, so they adjust until they get things running again. They do have co-op agreements with a few fabricators in the area, which can help in a crisis. And operating 24/7 gives them the opportunity to fix a process and catch up during the next shift. Maintenance people are available at any hour of the day to ensure things keep humming.

Equipment Upgrades

Although the operations are well-controlled and thought out, the company can benefit greatly from some newer equipment. There are a few new purchases in the wings, which Viter discussed while we were touring the factory. They're looking at a new two-spindle drill machine and a direct imaging system, both of which are designed to increase throughput and improve capabilities. I'm sure these new systems will also help maximize the factory production footprint. There's also an OEM press on order that happens to be the only one small enough to fit in the space of the old press, and they're continuing to upgrade as it makes sense.

As I mentioned earlier, Sunstone's commitment to remaining profitable has driven their efforts to maximize usage of existing equipment and processes. They prefer to make smaller, budgeted, methodical moves when it comes to capital equipment. They don't have to climb the technology ladder too quickly to meet the needs of most of their customers for 5/5 technology. Instead, their focus is on speed and customer service. How can they move boards more quickly through the factory and out the back door to the customer?

Management Experience

As I talked with the management team and factory floor employees, names like Tektronix, Merix, Praegitzer and Viasystems, popped up. It seems that Sunstone has been the beneficiary of the talent of a few of its neighbors and bygone shops. The rest of the company employees have been homegrown over the last decade or two. More on Sunstone's managers in the sidebar.

The Guarantee

Putting their money where their mouth is, they've upped the ante by attaching a guarantee. If they don't "deliver quality boards, on time with the right quantities," then the order is free.

I think if most of us realized we were going to be late, we would prefer to work with customers to see if they were OK with the delay or to see if we could make partial shipments, etc. We wouldn't discount our work unless we had to. In fact, most customers would probably be fine with a delay, here and there, as long was the communication was good. They're kind of used to that.

When the idea of a guarantee was first floated at Sunstone, some thought it was a bit too much. But after a review of their delivery history, they decided to make that offer and stand behind it. They have had to eat a few orders since they first instituted the program, but the process improvements they've made as a result have benefitted the company way beyond the cost. They've had to step things up but it's been a win for the company and a win for the customers.

Although I might have ruffled a few feathers among senior managers when I called the guarantee a gimmick, I did follow that up by saying that offering a guarantee does three things. It gets people's attention, it demonstrates confidence, and it helps ensure customer loyalty. The gimmick is what we see on the outside, but the systems and people behind it, as well as the effect is has on the customer, are the real thing.

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The Sunstone Team

In the words of Director of Manufacturing Nancy Viter:

At Sunstone, the philosophy of empowerment is more than just a catch phrase. Each team member is a leader in his own way, and understands that the responsibility to give the customer the best experience possible falls squarely on each individual's shoulders. The beauty of this way of thinking is that there is very little finger-pointing when problems arise. Team members are expected to contribute to the solution, regardless of the challenge. If a piece of equipment goes down in the middle of the night, waiting until morning when a leader arrives is not an option. This builds teamwork, as all available resources come together to share manpower and knowledge. Are there teachable moments that might result in a well-meaning, but perhaps unsuccessful solution? Absolutely!

But individuals know that making a decision is better than doing nothing at all, and with all the years of experience and successful problem solving to call on, the risk of this empowerment philosophy is minimal. From the head of the organization all the way to the newest, youngest staff member, Sunstone leads by example, whether there is a title attached to the name or not, and this concept is taught in word and deed as new hires are trained.

All that said, here is a snapshot of some employees who contribute to our success daily:

Rocky Catt (41 years), co-owner: With 30+ years of experience, Rocky has served as a line supervisor, general manager and is the vice president and COO of Sunstone Circuits, where he oversees the company's operations.

Terry Heilman (16 years), co-owner: Terry oversees all corporate operations, strategic marketing and financial planning for the company, and Sunstone's significant growth reflects Heilman's guidance and contribution to providing the most extreme customer experience in the industry.

What I liked most about the guarantee is the opportunity it provides Sunstone to improve the process. I remember when Motorola went to Six Sigma (zero defects) as the quality standard to strive for back in the 1980s. They realized that if they chose the more attainable goal of Three Sigma they could continue to do the same things just a little better. With Six Sigma they'd have to change everything. It caused a revolution in their manufacturing. In my mind, the guarantee is that kind of an effort, and it would cause many in the industry to have to reinvent their companies. Still, many companies will tell you that they're 100% on time but when you really look at the data, that isn't the case. There are lots of exceptions used when calculating that number. The Sunstone guarantee, from what I gathered, is that they honor the guarantee regardless of the situation without input from the customer. If they don't do what they say, they pay. As a result, over 50% of the customers who've received free boards are pleasantly surprised.

Open all Year

That's another differentiator the company uses to expound on their customer service. They are always open, and available to take customer calls. Heilman was unapologetic when we talked about the commitment behind this next level of service. "Why not? Why wouldn't we offer this to our customers? Shouldn't they be able to talk to somebody whenever they want? If it's important to them to know the status of their boards or to try and solve a problem on New Year's Eve, shouldn't it be important to us, as well?"

The Squeeze

Since I'm not a maker of prototypes, I haven't been noticing the effect that improvements in PCB design software has had on this segment. It seems that the software is getting pretty good. In fact, as Viter pointed out, they're seeing fewer and fewer PCB revisions. Customers are now able to prove out designs in software, pretty much, which leads to fewer prototype orders.

Better design software, emerging technologies like printed electronics and other engineering prototyping systems will continue to pressure the company in the coming years. But that's where Heilman and Catt come in.

The Future

The partners are keeping their eyes open for opportunities to grow and expand their business. Landlocked in their current facility, any substantial growth will require an additional facility, an idea which is on the table. Neither Heilman nor Catt are in a hurry to grow, but when they do, they will likely do it carefully and methodically—not just for the sake of growth. Heilman's extensive background with M&As and business management should help them avoid many of the pitfalls associated with mismatches so common in typical M&As. Expansion, acquisitions, adding value to the services they already provide to their thousands of customers in the PCB industry are all on the table. They are very profitable, debt free, growing and having fun. It would seem to me that Sunstone is ready to make a carefully calculated next move. **PCB**

The Sunstone Team *(Continues)*

- ***Sheri Kuretich (21 years),*** human resources
  Ed Graham (38 years), safety and environmental
- ***Bill Moffatt (28 years),*** maintenance
  Lynda Postlethwaite (30 years), sales and customer service
- ***Joe Phelps (16 years),*** automation programming/ CAM support
- ***Wayne Austin (31 years),*** CAM
- ***Tammy Russell (27 years),*** mechanical operations
- ***Donna Miller and Cindy Marshall (64 years combined),*** line
- ***Bill and Sue McDowell (50+ years combined),*** imaging and plating
- ***Jake Taylor (11 years) and Mike Hebda (12 years)***
- ***Karen Brugger (23 years),*** quality
- ***Carrie Adams (30 years),*** (LPI)
- ***Albert Wolf (36 years),*** (LPI)
- ***Trina Taylor (16 years),*** imaging
- ***Doug Miller (7 years),*** shipping
- ***Mike Connella (7 years), Jeff Loewen (7 years), Tom Hall (10 years), Carrie Ditton (8 years), and Dennis Hammer (<1 year)***
- ***Kelly Atay (10 years),*** administration
- ***Teresa Burtis (17 Years),*** administration
- ***Mike Butler (5 Years),*** IT
- ***Sal Hernandez (8 years),*** customer support
- ***Matt Rhodes (4 years),*** customer support

And then there is me, ***Nancy Viter.*** I consider myself more of a cheerleader, although I could be considered a director of a beautiful orchestra that is made up of the entire Sunstone team. Each individual is like a finely-tuned instrument, and we make beautiful music together. Everyone knows his part, plays it dependably, and the unique Sunstone symphony would be difficult, if not impossible, to copy. We play for a very special audience: our customers and one another.

Aluminum Base Circuit Technology: Structures & Manufacturing Methods

by Joseph Fjelstad
VERDANT ELECTRONICS

Abstract

Aluminum is an attractive material for use in the manufacturing of electronic assemblies, owing to its low cost, good thermal properties, dimensional stability, environmental friendliness and ubiquity. Unfortunately, due to its innate thermal spreading ability, it is not easily used when solder is required to make interconnections to components. This article describes ways to manufacture electronic assemblies using aluminum as a base and eschewing the use of solder.

Introduction

RoHS restrictions on the materials used in electronics manufacture have imparted significant challenges on the electronics industry since their introduction in 2006. The greatest impacts have been felt by the mandated elimination of lead from electronic solder, followed by the demand for the elimination of haloids from flame retardants used in traditional PCB laminates. Since 2006, the electronics industry has been beset with a host of new challenges in its effort to comply. Failure mechanisms, both new and old, have surfaced which demand solution and the industry suppliers and manufacturing technologists have worked diligently to remedy those vexing faults through the development of a wide range of new materials and equipment for both board manufacture and assembly, along with modifications to the processes used in the manufacture and assembly of printed circuit boards.

Most of the problems which have confronted the electronics manufacturing industry have related to the solder assembly process. Lead-free solders were advertised early on as a drop-in replacement for traditional tin lead solders; however, field experience proved it not to be the case. The tin-rich alloys, along with the higher temperatures required for assembly, cause the industry to scramble for solutions to such problems as champagne voids, poorer wetting, brittle solder joints, copper dissolution, tin whiskers, head-in-pillow, greater vulnerability to damage caused by explosive outgassing of absorb moisture in packages among others

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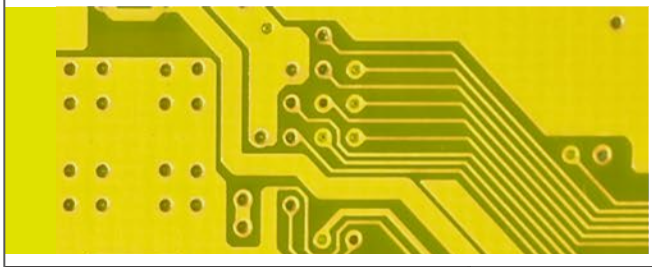

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including cleaning of baked on fluxes following the high temperature assembly process. Lead-free solder also had spillover effects on the PCB laminate material itself as manufacturers experienced delamination and degradation of the resins used in traditional circuit construction. One more recently encountered problem is a phenomenon referred to as pad cratering, wherein resin beneath the copper land to which a component is attached is actually torn loose from the surrounding resin breaking through the copper and causing an open.

In this environment, an alternative approach to manufacturing electronic assemblies has been conceived and is presently being developed. The new method in simplest form is one which eschews the use of solder and is predicated on the use of aluminum substrates which house fully tested and burned in components to create what can be best described as a component board wherein the terminations of the components are proximately planar with the surface of the aluminum. In subsequent processing the aluminum component board is first coated with an insulating material and then circuits which interconnect the components are applied using buildup technologies. An example of a solderless test vehicle assembly is shown in Figure 1.

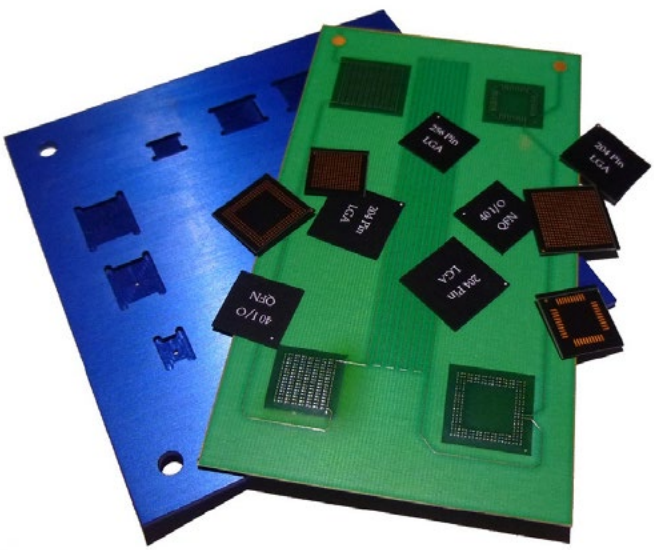

Figure 1: Aluminum is a viable alternative to customarily used laminates when solder is not used to make interconnections between components and circuits. Aluminum is unique in that its surface can be anodized, creating an insulation layer of alumina which can be colored and sealed. All components shown have a purposely selected 0.5mm contact pitch for reasons discussed in the text.

The balance of this article will describe in more detail the processes used in the manufacture of such product and enumerate the numerous benefits that can be derived by simply reversing the manufacturing process. That is placing circuits on component boards rather than components on circuit boards.

Basis Manufacturing Concept

A new process for manufacturing a PCB which is comprised primarily of aluminum is hereafter described. The novel process bypasses completely the soldering process in accordance with the precepts consistent with what is known as the Occam process[1,2]. The Occam process is a subset of technologies that fall under the general umbrella term of SAFE an acronym which stands for either "solderless assembly for electronics" or "solder alloy-free electronics." SAFE manufacturing is relatively simple compared to traditional circuits, and the cost should prove significantly lower.

In brief, the process is carried out by placing electrically tested and burned-in electronic components onto an aluminum carrier plate/housing. This can be performed using traditional pick and place equipment. The resulting structure is fundamentally a component board. Following secure placement of the components, processing methods traditionally used for the manufacture of HDI buildup boards are carried out on the surface of the component bearing aluminum assembly to produce circuit patterns with the interconnection between components and circuit pattern being effected by copper plating of both the circuit features and the vias which interconnect component leads to those circuit features at desired locations. One advantage of note at this point is that unlike soldered devices, only those component leads requiring connection need be provided with vias. In addition, the vias are smaller than the traditional solder lands so more surface area is available for

circuit routing. This will be discussed again later in the paper.

Aluminum is an attractive choice as a circuit substrate owing to a combination of different properties, which include a coefficient of thermal expansion reasonably proximate to that of copper, dimensional stability which exceeds that of FR-4, relative light weight, good thermal spreading capability, and low cost (aluminum is roughly $2 per kilogram, while FR-4 in quantities of 2,000 kilograms coming out of China runs around $6 per kilogram[3]). It is also worth noting that aluminum comprises 8.3% of the earth's crust and is highly recyclable positioning it among the most sustainable of all circuit substrate choices.

Turning attention back to the steps in the process, a sheet of aluminum is prepared with cavities wherein components will be placed. Because the substrate is solid metal, the cavities can be created by any of a number of steps including chemical machining, mechanical machining, laser cutting and punching. The substrate could also be embossed or cast with the cavities if desired.

Aluminum is a unique metal that can be anodized, converting the surface to aluminum oxide, also referred to as alumina. As a conductive material, aluminum can also be coated electrophoretically with a plateable insulating material, making the surfaces nonconductive. Such techniques are commonly used in the coating of a wide range of metals used in products of every imaginable type from toys and household appliances to automobiles and space craft.

The cavities receiving the components are ideally formed such that the depths will match the components' height so that when components are placed into their assigned cavities with leads facing up, the lead terminations will be flush with the surface to facilitate further processing. Figure 2 illustrates the basic steps that follow and will be discussed in more detail.

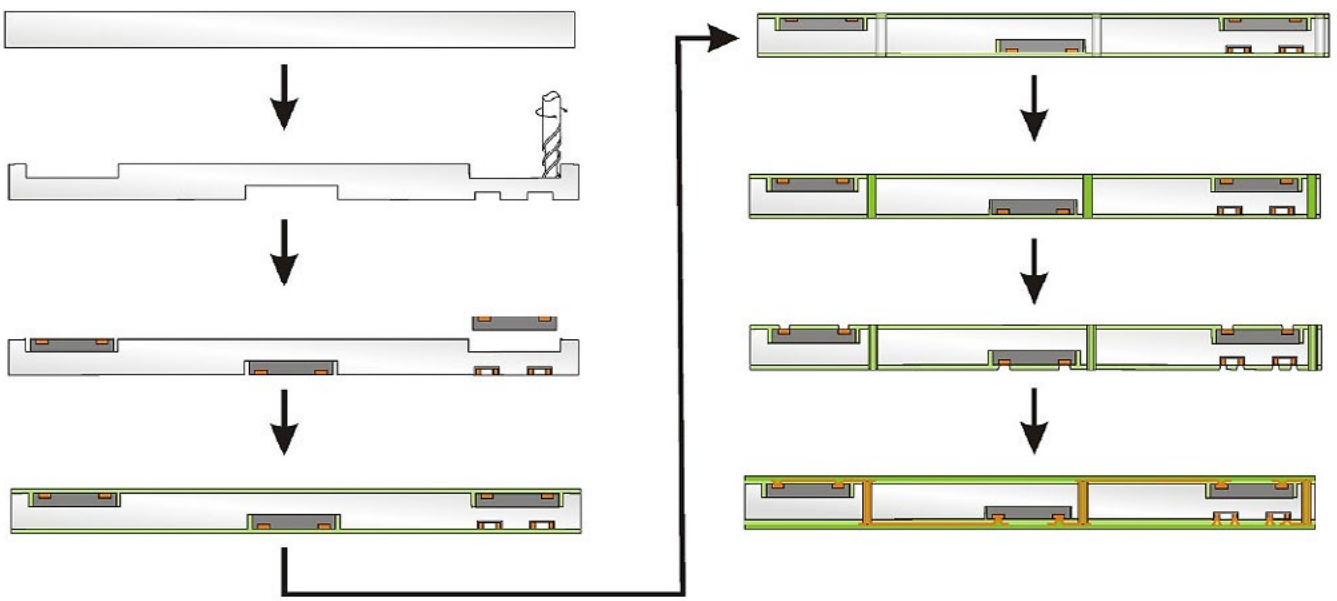

Figure 2: The basic process steps for double-sided aluminum circuit assembled and interconnected without solder are illustrated from the top left; aluminum material is provisioned with cavities by milling (as illustrated),etching or embossing, wherein components are placed and then coated with an insulating material. Holes are drilled and then filled with insulating material, then re-drilled. At the same time, vias are formed to access component terminations. The circuit pattern is then plated and circuits sealed after last layer is complete, leaving open feature required for interconnection and power (open features not illustrated). The metal core can serve both as heat spreader and power or ground layer.

While the use of bare die is possible, the IC components to be used are ideally packaged (CSPs are very well suited) because packaged IC devices are much more easily tested and burned in and because they have standardized lead patterns and physical outlines making the design process simpler, especially if a single lead pitch is used for all components (e.g., 0.5 mm). Additionally, nearly all packaged components use copper as the base metal for interconnections, which is advantageous for more than just that one reason alone, as will be shown.

After the components are affixed permanently on one or both sides of the aluminum carrier plate, layers of insulation are applied to one or both surfaces of the metal sheet covering the components. At this point, the assembly can be processed as if it were a standard rigid printed circuit with high density build-up layers on one or both sides, using lasers to drill holes down to access component terminations and commonly practiced plating and imaging processes to create the circuits. A difference is that a fill step with an insulating material may be required if through-holes have exposed metal. However, if coated with epoxy, this may not be necessary. One caveat for those circuit manufacturers considering exploring processing circuits of this type is that if the aluminum is untreated, the edges need to be sealed to prevent contamination of subsequent processing chemistries that will be used in manufacture. While additional processing steps can be performed if desired and or required, this assembly could be in some applications considered complete. The overall number of processing steps is obviously significantly reduced from those required for traditional processing of printed circuit assemblies.

While the foregoing has described a relatively simple structure the longer-range potential of these novel aluminum circuit structures is impressive and limited more in my imagination than the technology. One such example is illustrated in Figure 3.

> ***In a highly cost-competitive global economy, the cost of manufacturing is always a high order concern. Looking first at material, the reader is asked to note again that the primary material of interest in this discussion has been aluminum. Aluminum is the third most abundant material on our planet (oxygen and silicon are first and second, respectively).***

Advantages of Aluminum Circuit Assemblies

Beyond the structures just described, there are a striking number of advantages to the design and manufacture of electronic assemblies that do not use solder to make interconnections, especially those made with aluminum. However, the advantages of products manufactured using SAFE techniques also circumscribe the full range of benefits normally considered desirable for any electrical or electronic product. Following are brief discussions of those benefits:

A. Economic Benefits

In a highly cost-competitive global economy, the cost of manufacturing is always a high order concern. Looking first at material, the reader is asked to note again that the primary material of interest in this discussion has been aluminum. Aluminum is the third most abundant material on our planet (oxygen and silicon are first and second, respectively). As was mentioned earlier, it comprises 8.3% of the earth's crust. Because of its commodity status, aluminum is sold by weight regardless of thickness and it is less expensive per unit volume than composite materials. Though aluminum is admittedly denser than FR-4 laminate (2.8 g/and in cm^3 aluminum versus 1.8 g/cm^3 for FR-4), the amount of aluminum required can be very cost competitive in the long run. In contrast, the price of polymers varies due to the volatility of the price of oil, so there are advantages to being able to use a material such as aluminum, the price of which is reasonably predictable because of its global abundance.

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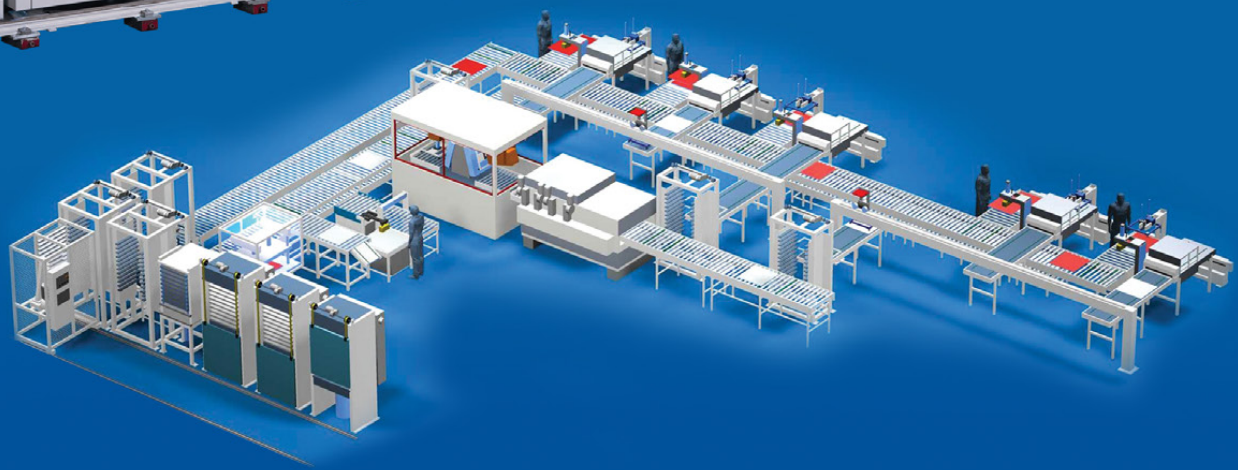

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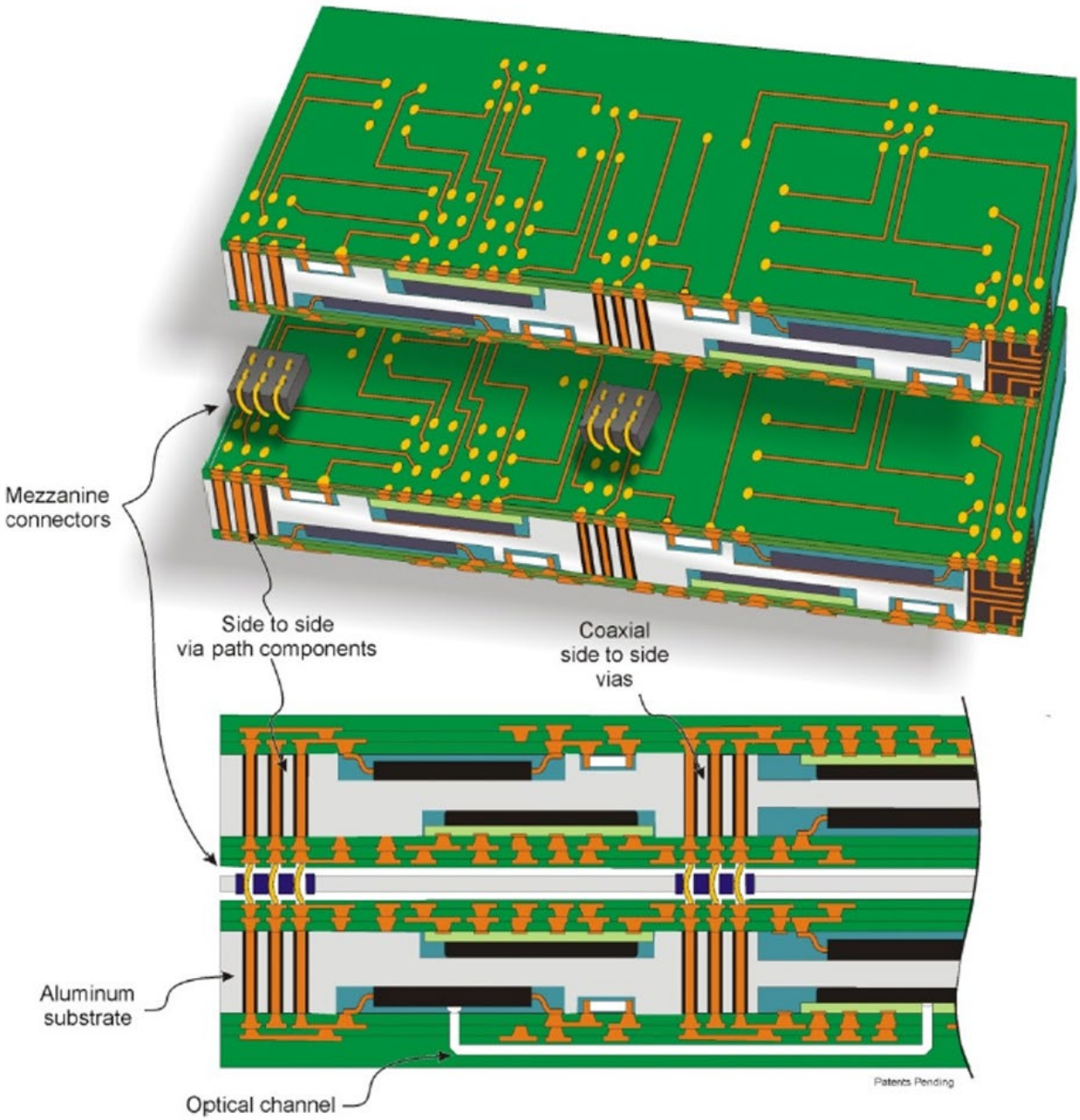

Figure 3: Solderless aluminum substrates can potentially be stacked and interconnected and even "bolted" together using mezzanine connectors to create aluminum bricks that may simultaneously solve a range of problems related to both performance by creating shortest path routing and the thermal challenges that often accompanies higher performance. Note that optical interconnection opportunities also exist as optical ports are commonly provided on the edges and/or the bottom of optical devices making provision of stable optical channels.

Next, the number of manufacturing steps is reduced significantly, lessening manufacturing cost. What should be highly evident is that the entire soldering process with its many steps and requirements is omitted. No stenciling of solder, no paste inspection, no reflow, no post-assembly cleaning, etc. There is also no need to be concerned with moisture sensitivity of

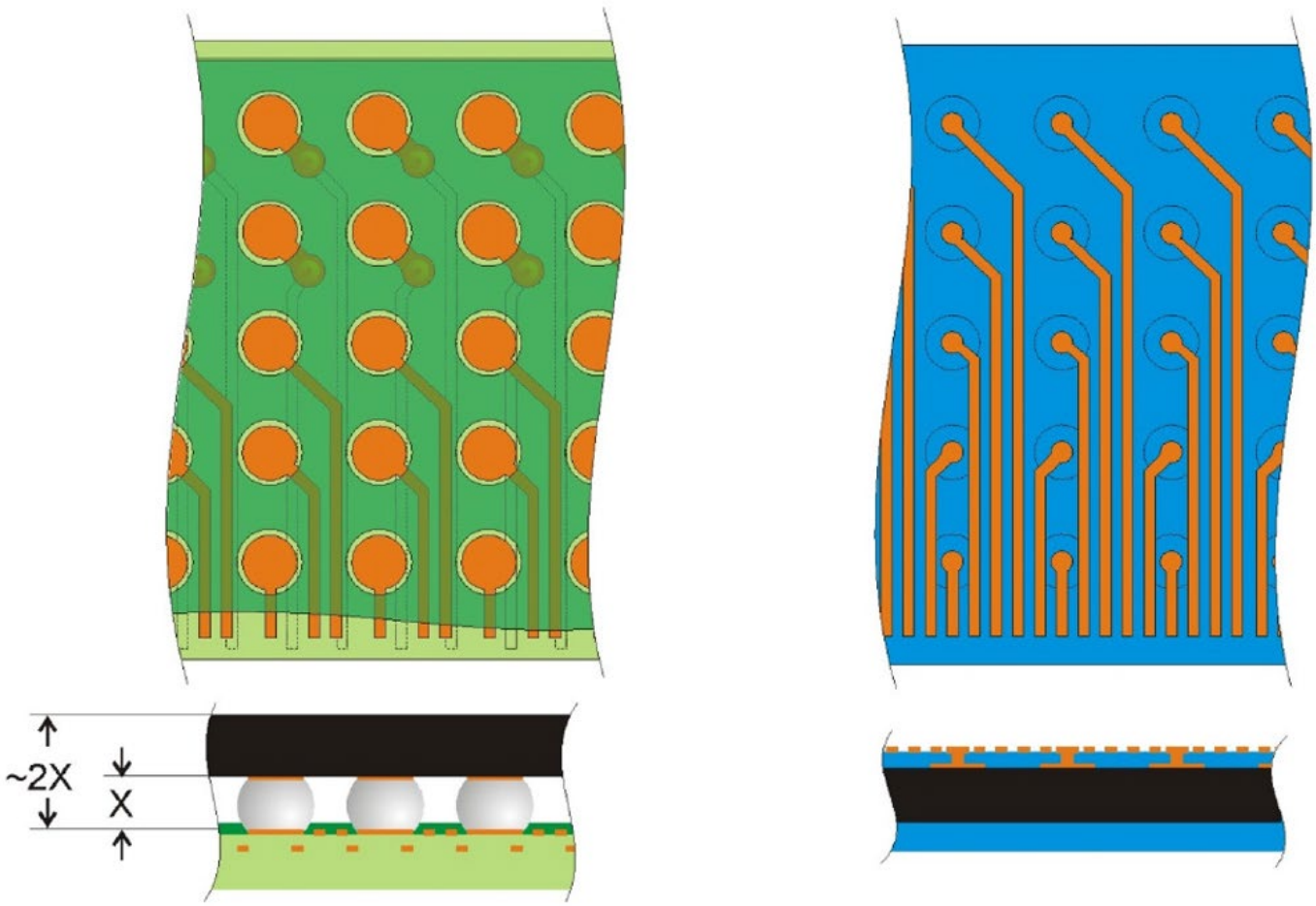

Figure 4: At any given lead pitch, solderless assembly methods can significantly reduce both layer count by freeing up routing space and assembly height as solder often makes up half of the overall height of a mount package.

components. Thus the energy and time wasting baking steps that are commonly called for in conventional processing are obviated. Depending on the complexity of the design, as it has been estimated independently by a number of manufacturing experts, the final cost of such assemblies could be 25–35% lower than traditional methods (exclusive of the component cost). The actual savings will depend on the specifics of the design and savings may be less, however any savings in today's highly competitive global markets is both welcome and highly prized especially if the final product is not subject to intense environmental scrutiny in search of metals and materials which are proscribed by EU regulations.

Another economic benefit is that the components used do not require special finishes to maintain solderability, nor do they need special treatment to keep out moisture because they will not experience the high temperatures required for lead-free solders. Eliminating the finish can and should reduce the cost of the components at some point in time; however, it is possible that electronic component suppliers may in the near term charge a premium to the user for not adding solder balls or nickel-gold finishes processes. Finally, reliability also has an economic impact as warranty payouts for failed products can quickly cut into profits while simultaneously undercutting the manufacture's reputation.

B. Electrical/Electronic Benefits

Such constructions as have been described offer several electrical/electronic benefits. For example, where connections are made to terminations on component lands, the point of interconnection can be made without benefit of a large pad, which can reduce parasitic capacitance. This also frees routing space, allowing for a potential reduction in total layer count, and further reduces cost (Figure 4). If proper planning is used in choosing components of a common grid pitch (e.g., 0.5 mm) the integrated power mesh system (IMPS) design layout approach may be employed, thus reducing layer counts while improving signal integrity. With proper preparation, the aluminum core can serve as power or ground as mentioned earlier. This makes it possible to provide both power and/or ground immediately adjacent to every component. Finally, the completed assembly can also be relatively easily provided with metal plating after the assembly is complete making the entire assembly metal jacketed and thus EMI- and ESD-immune, as well as nearly hermetic, exclusive of those areas left open for external I/O connections.

When aluminum is used as carrier, it becomes by default a heat spreader which is an integral part of the assembly. This allows the designer to address thermal concerns early. Given the inverse relationship between long-term reliability and the number, temperature extremes and durations of the thermal exposures a component experiences, having a built-in thermal management solution is an intrinsic value-added feature.

C. Thermal Benefits of Aluminum Substrates

When aluminum is used as carrier, it becomes by default a heat spreader which is an integral part of the assembly. This allows the designer to address thermal concerns early. Given the inverse relationship between long-term reliability and the number, temperature extremes and durations of the thermal exposures a component experiences, having a built-in thermal management solution is an intrinsic value-added feature.

D. Mechanical Performance Improvements

Since the components are encapsulated in the aluminum assembly and thus part of an integrated whole, they are fundamentally immune to the effects of shock and vibration. The CTE (coefficient of thermal expansion) of aluminum and copper are relatively close (22ppm/C vs. 18ppm/C), which reduces the potential stress on interconnections; moreover, the materials expand predictably in all directions, whereas reinforced laminates have CTEs that may vary in X, Y and Z dimensions, sometimes quite appreciably (e.g., X ~20ppm/C, Y ~23ppm/C and Z ~80ppm/C).

The microvias which are used to make connections to components and to any additional build-up layers have been proven superior to solder joints, and (though there was recent report of microvias also being damaged by the lead free soldering process). Moreover, there is possibility in some cases to use relatively thin aluminum base material, which could allow the developer to bypass the final etching process and permanently form the final assembly into the desired shape, opening up new possibilities to the clever product designer.

E. Design Security

The methods suggested offer a design security benefit that may not be immediately obvious to many product developers. The methods employed obscure the components used in fabrication, making tear-down and reverse engineering of a product much more daunting and difficult for those wishing to understand what might differentiate the product in hand with previous competitive products. This benefit extends to all kinds of products, from consumer

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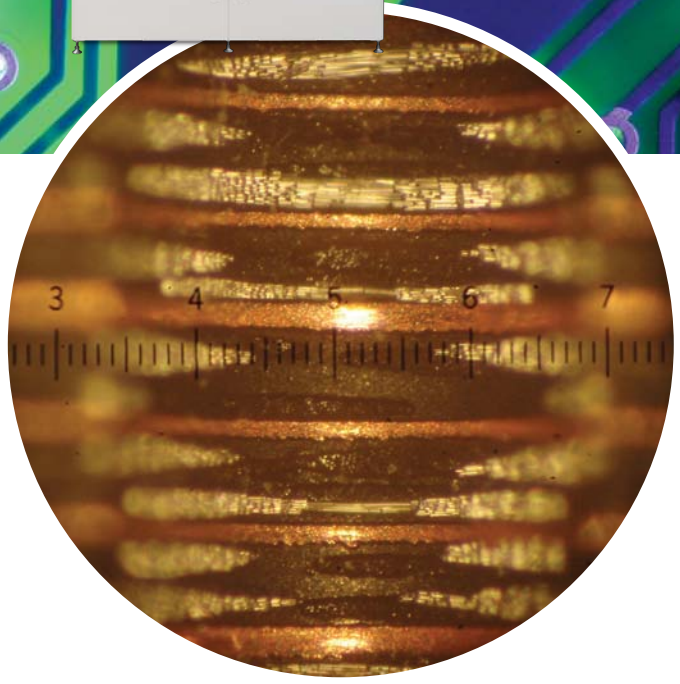

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to military. Furthermore, the assembly makes it much more difficult for unscrupulous individuals to extract and reuse components, injecting them into the supply chain as counterfeit devices[4].

F. Reliability Improvement

Improvement in reliability is largely a by-product of various elements of the electrical, thermal and mechanical performance benefits just discussed, combined with the benefits that can be obtained by simple bypassing of a high-temperature lead-free soldering process. To this point, it is worth repeating what was mentioned earlier and that is that the soldering process is typically the largest cause of defects in assembly and that solder joints are the most common sites for failure of electronic interconnection systems[5,6]. Furthermore, in a solderless assembly, concern over tin whiskers, a topic that has returned to prominence in recent years, is relieved. Finally, CAF[7] (conductive anodic filaments), which is the growth of conductive fibers between adjacent vias in reinforced materials and tin whiskers[8] are obviated by the ability to use homogeneous, unreinforced materials and elimination of solder respectively.

G. Regulatory Compliance

The EU's RoHS legislative mandate to eliminate lead from electronics solder has proven very costly[9]; however, this stricture is automatically accommodated if one eliminates solder completely. The finished structure described is basically an all-copper interconnection system. On the finished product, only the surface sites required for making electrical connection to the other system elements, such as switches, connectors and the like, need to have a contact finish. The key point is that since neither copper nor aluminum is considered a problem, both the RoHS and REACH concerns should be obviated provided the other materials selected and used in the assembly are compliant. Additionally, the material declaration process is greatly simplified. These same benefits hold true relative to the use of conflict materials which is of growing concern among increasing numbers of both governmental and non-governmental organizations (NGOs) as the structures completed as described are completely devoid of any proscribed or sanctioned materials. In short, the assemblies described allow a product to much more easily pass regulatory scrutiny.

The key point is that since neither copper nor aluminum is considered a problem, both the RoHS and REACH concerns should be obviated provided the other materials selected and used in the assembly are compliant.

H. Environmental Friendliness

During the last few decades, concern over the environment has moved steadily into the consciousness of government officials, business leaders and the consuming public around the world. The term social responsibility is also often used to describe the concern; however, the fact that the industry makes products that impact the environment at the lowest possible level has become increasingly important. With that in mind, consider an electronic structure constructed principally of a material that is desirably and easily recycled, such as aluminum, as well as the significant amount of energy that is used in traditional manufacturing in component and assembly preparation and in the soldering process—which can be saved when solder is not used. As suggested earlier, additional energy savings can be found by obviating the need for all of the process steps leading up to and following the soldering process.

Discussion

As has been shown, there are many advantages to making aluminum circuit assemblies in the manner described. That said, a recurring question is often raised: How does one test and rework such assemblies? The question is perhaps best addressed with another question: If the process is executed properly and the components are not subjected to thermal extremes,

why should there be a need to test and rework? The simple fact is that most electronic assembly problems are related to the inherent weakness of the soldering process and solder joints failure remains a leading cause especially when there is shock or vibration[10]. Moreover, below 0.5 mm lead pitch, which is where the component roadmap trends are headed, assembly yields drop off appreciably, even with multiple preassembly inspection steps implemented and/or applied. The EMS industry has come to accept the weakness of its assembly and cleaning processes even as it strives to constantly improve them, making marginal improvements through new materials and equipment and as a result has come to also expect that rework and repair are a natural part of the manufacturing process. This acceptance carries with it what can be best described as a self-defeating ingrained attitude and results in the manufacturing having to continually carry out a process that might otherwise be made unnecessary. In short, if the components are fully tested and burned-in and the processes used are properly controlled, the final product should be high-yielding, provided the design is inherently valid and robust. The limits of reliability of future electronic products could well be better defined by IC reliability than the reliability of the circuits and plated vias that are used to interconnect them.

Conclusion

The aluminum circuit structures as have been described in this article are simple to design and eminently possible to manufacture. They can be easily produced using well-established manufacturing infrastructure tools, equipment and processing techniques which are simply reordered to make highly useful electronic products suitable for use in everything from consumer to high-reliability automotive, military and aerospace products. The limits are likely to be defined more by the imagination of the designer than the limits of the fundamental technology which has been described.

Acknowledgment

The author humbly acknowledges the support of the members of the Verdant Electronics Advisory Board, who have offered their unwavering encouragement and sound advice for the last seven years. **PCB**

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Verdant Electronics Founder and President Joseph (Joe) Fjelstad is a four-decade veteran of the electronics industry and an international authority and innovator in the field of electronic interconnection and packaging technologies. Fjelstad has more than 250 U.S. and international patents issued or pending and is the author of *Flexible Circuit Technology.*

3D LDS Components: New Opportunities in PCB Layout and Production

by Malte Borges
LPKF

One clear trend has dominated electronic and mechatronic products for many years: components must get smaller in size while also packing in more functions. Manufacturers in the communications technology sector are under tremendous pressure to continuously launch new products on the market at shorter and shorter intervals, to maintain their commercial positions. As if that were not enough, these new products have to stand out from the crowd by offering unique selling points. Innovative technologies such as MIDs (molded interconnect devices) enable new products to be produced with unprecedented functionality. And this is where LPKF's LDS technology comes in because it opens up a huge opportunity for businesses that need very reliable and efficient production technology. Economic prototyping processes and a short production pipeline are also added advantages.

The current main application is the production of smartphone antennas. In the future, the German Research Association 3D-MID expects a significant growth in tablet or laptop antennas as well as new applications in the automotive and medical field.

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MIDs allow the integration of electronic circuits and components directly on three-dimensional plastic components. This enables chips to be elegantly stacked in their assemblies, and the antennae in smartphones or netbooks to be incorporated directly within the housing, which saves a great deal of space. Integrating functions also decreases the number of individual components required, eliminates a whole range of production steps, automatically saves additional costs, and creates higher quality components.

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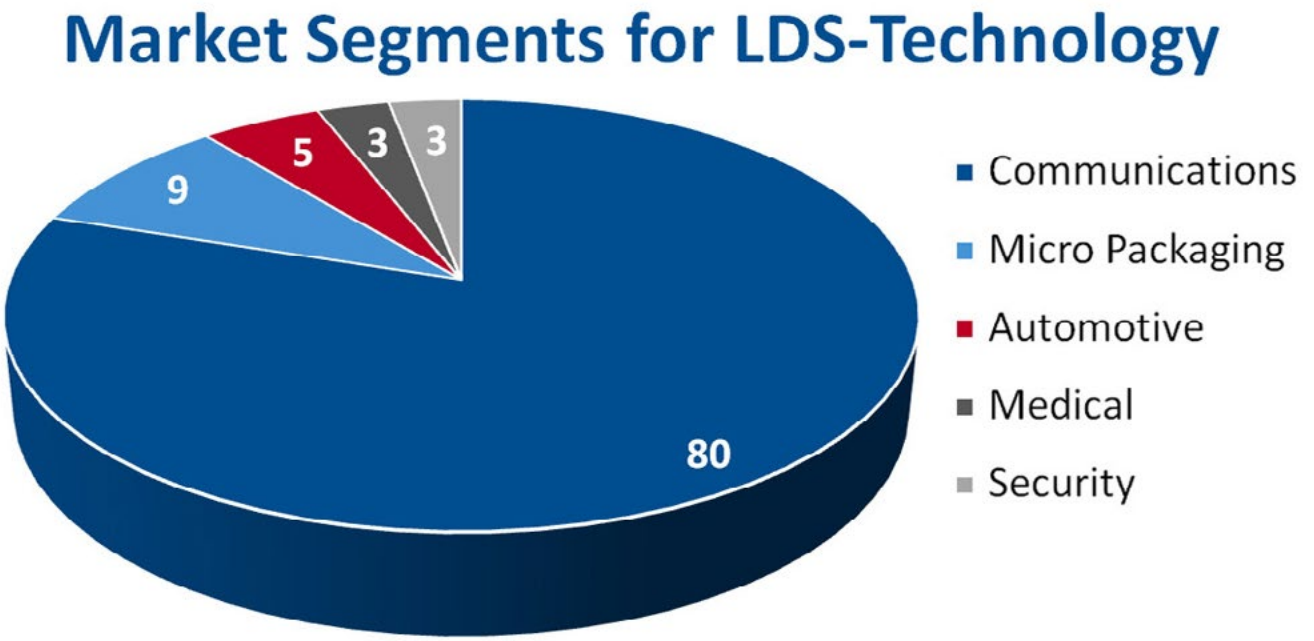

Figure 1: Differentiation of the use of LDS systems by market segments (3D-MID e.V.).

The most common methods for integrating electronic circuits directly on plastic components are:

• Hot stamping, using a die to press thin flexible films onto a plastic component: Excess film is then removed. This method is simple and works with a large range of materials. The problem is that this method is incapable of creating fine tracks, real 3D structures, and complex circuits. A change of layout data also requires a new film or a new stamp tool.

• The two-component injection molding method: This works by using the first metallizable polymer to mold a structure with the circuitry at the surface. The second polymer is not metallizable and covers those areas without conductive tracks. This method allows a great deal of 3D design freedom, but it needs high upfront costs and is restricted to only a few types of plastic. Two complex injection molding tools are required. Creating fine tracks is also a problem. Another negative aspect is the relatively long time needed to successfully push products of this kind through the product pipeline and onto the market. The lead time for the development of injection molding tools alone is around two months, but in very high series without layout changes this method is very economical.

• The subtractive method: This method uses a laser to remove metal layers where they are no longer required, or to open a resist for the subsequent etching process. This method requires long laser exposures, and components with fully metallized surfaces.

• The Laser Direct Structuring method (LDS): Patented by LPKF, this method provides further advantages, both technically and economically. The LDS method uses a thermoplastic polymer doped with a laser-activatable metal-polymer additive. When the laser beam hits this polymer it activates the metal complex and creates a precise track with a rough surface. Exposed metal particles form the nuclei for the subsequent metal coating process. The laser beam therefore draws the structures required on the component so that the conductor layers are created precisely along these tracks in a currentless metal coating bath. Copper, nickel and a gold finish can be successively applied.

The LDS Process, Step-by-Step

All the special strengths of lasers such as high flexibility, speed, resolution and precision, are utilized in this process. If the circuit has to

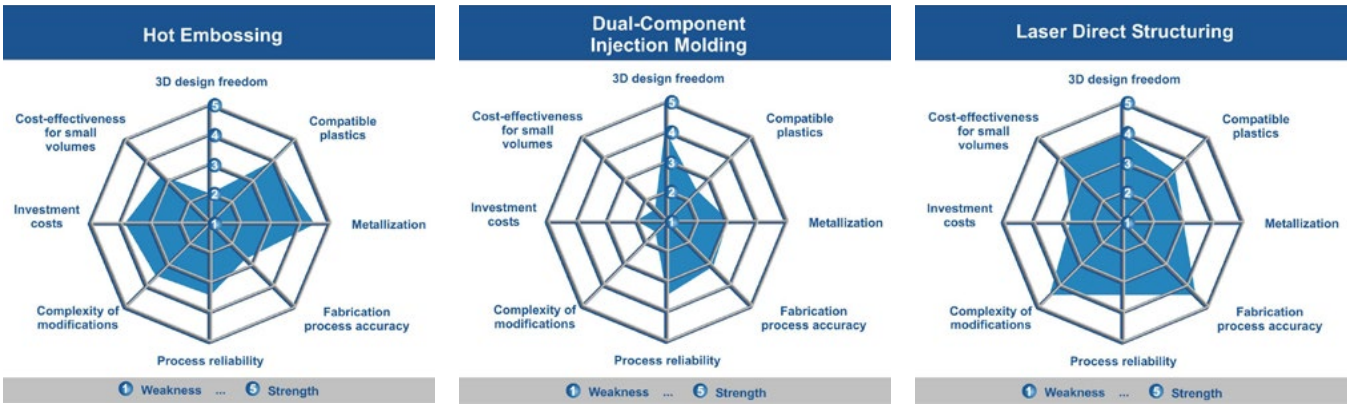

Figure 2: Assessment of 3D processes for interconnect devices, l–r: hot embossing, dual component injection molding, LDS.

be reconfigured, just feed a new set of control data into the laser unit. This means that one basic component can be used to create a range of parts with different functions—merely by changing the design of the circuits drawn by the laser beam. And because these control data can also be changed during production, companies can produce small- and medium-sized series in a highly cost-efficient manner. Even producing one-off products is no longer an expensive technical headache. The pipeline from prototype to volume production is short and inexpensive—businesses can react quickly to the changing demands of the market.

LPKF uses processing units with a laser wavelength of 1,064 nm and a pulse frequency

Figure 3: The plastic part, made by an LDS doped thermoplast.

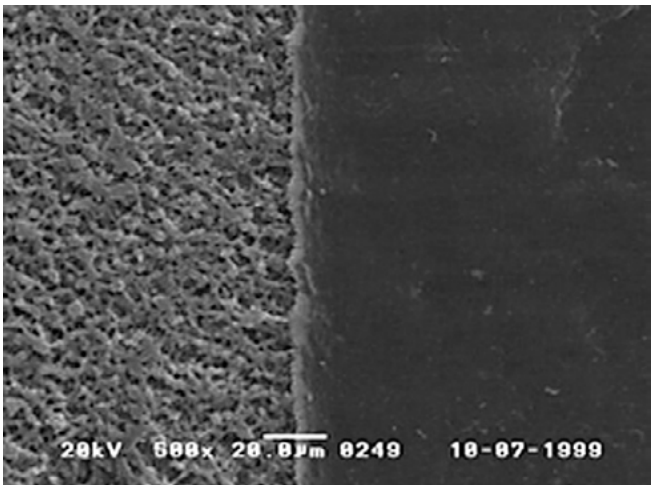

Figure 4a and 4b: The laser beam has structured the blank and has activated the additive.

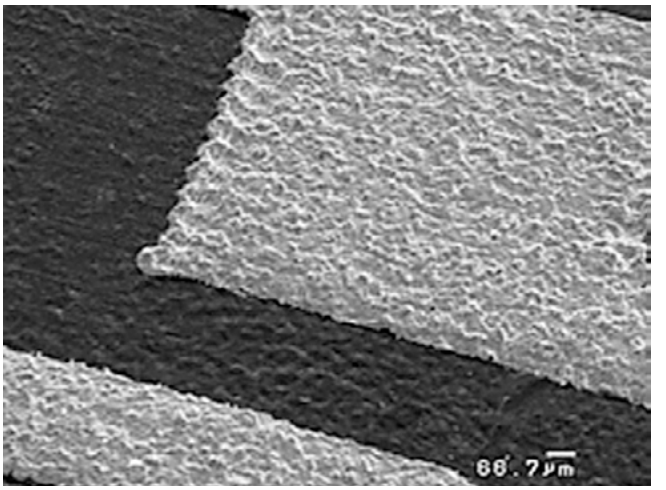

Figure 5a and 5b: In a currentless metallization bath copper settles on the structured parts.

Figure 6a and 6b: The structure may be connected via bonding or can be assembled with electronic components.

between 10 and 200 kHz. With its underlying technologies, the LDS method is particularly accurate. Implementing laser technology, circuit paths of 150 µm width and 150 µm spacing between the interconnects can be realized with the standard equipment, the standard system used up until now writing at a speed of 4,000 mm/s. With specialized laser sources and optimized focusing even finer circuit structures up to the ultrafine range are possible.

The laser structuring has to take place in a scan field up to 160x160 millimeters. A specialized laser system uses these parameters and a stitching routine to machine larger parts up to 400 millimeters in length. The LDS systems in the Fusion3D product line can be equipped with up to four processing units to greatly decrease the processing time.

Materials

The main prerequisite is that the metal oxide-containing additive has to be evenly distributed and sufficiently concentrated in the thermoplast. Now almost all leading plastic manufacturers offer LDS versions of their thermoplasts. The spectrum consists of amorphous and partially crystalline polymers, with thermal stability ranging from standard to high temper-

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ature thermoplastic. These include numerous types of materials that are suitable for lead-free soldering.

Here are a few examples of materials:

• Pocan® is a thermoplastic polyester based on polybutylene terephthalate (PBT) and polyethylene terephthalate (PET) developed by Lanxess. Pocan possesses a high resistance to heat distortion, and good strength and hardness characteristics. In addition it has high abrasion resistance, good chemical resistance, good electrical insulating and dielectric properties, high creepage current resistance and low moisture absorption. There are several variants of Pocan available to meet different temperature requirements. The material can be easily soldered and laser welding also produces the best results.

• PA6/6T is a partially aromatic polyamide based on Ultramid® from BASF AG. The material is distinguished by a high resistance to heat distortion and good mechanical properties. The short-time heat resistance can be increased up to 400°C (750°F) by using a crosslinkable variant of this material.

• A crosslinkable PBT (polybutylene terephthalate) based on Vestodur® from Degussa AG, with the good qualities of a standard PBT, also guarantees a high degree of distortion resistance.

• LCP (liquid crystal polymer) based on Vectra® from Ticona GmbH has a low melt viscosity and very high heat distortion resistance.

• PC/ABS (polycarbonate/acrylonitrile/butadiene/styrene) from DSM also has very good surface and mechanical properties.

Past LDS plastics were black because of the inherent color of black LDS additives. Now this restriction has also been lifted, as the innovative

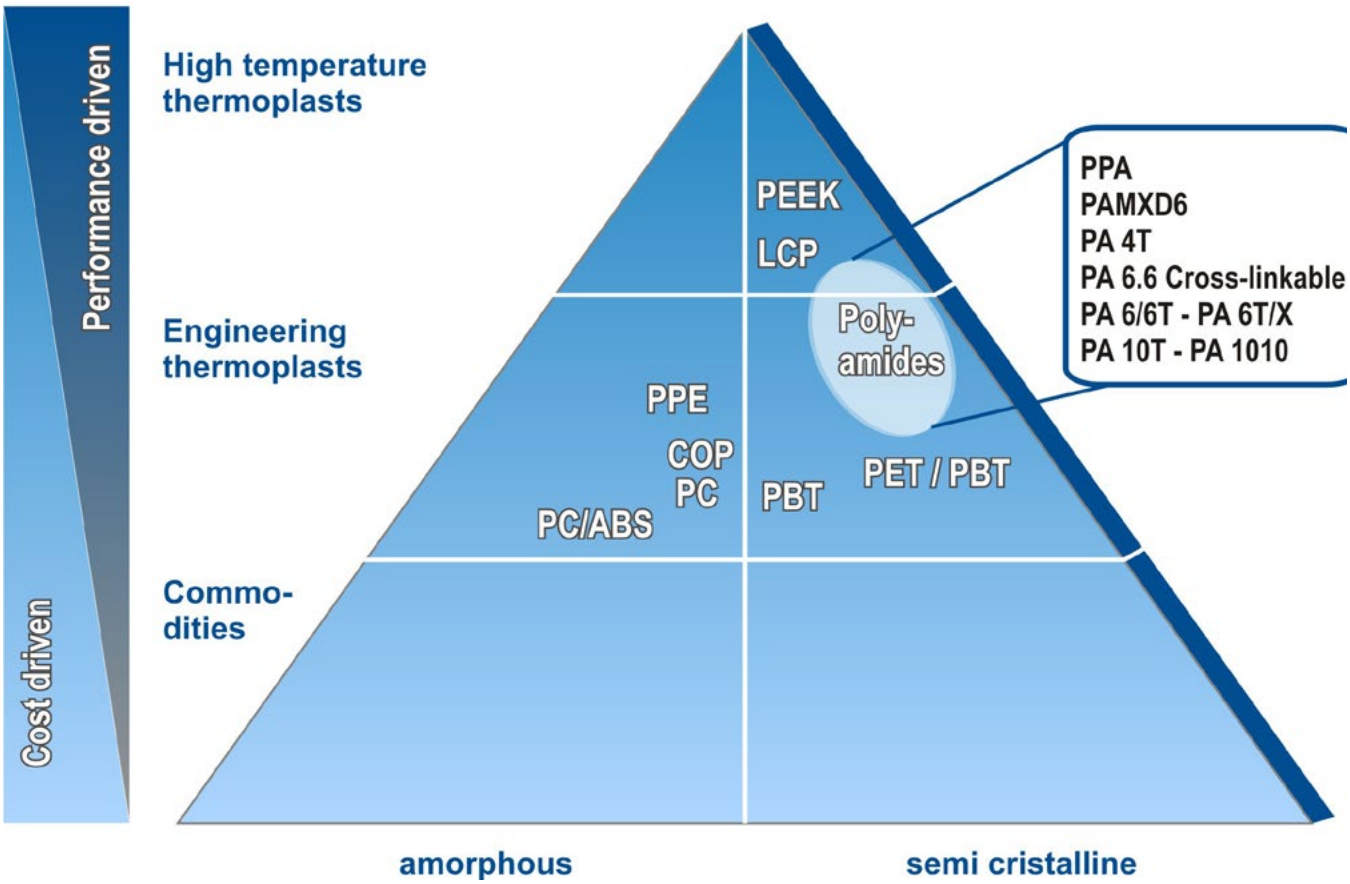

Figure 7: Plastic pyramid: almost all manufacturers offer their thermoplastics with LDS additive ex factory.

plastics units at SABIC and Mitsubishi Engineering Plastics (MEP) have both recently presented LDS materials which can be adapted to nearly all pigments that customers demand.

Design Rules

A complex procedure such as laser direct structuring of three-dimensional bodies requires some design guidelines for trouble-free and safe production. Here is an excerpt:

• The design should involve as few clamping and positioning steps as possible (short cycle times)

• Sharp-edged transitions should be avoided in the area of the structures to be metallized

• The recommended edge radius is 150 µm (100 µm is possible)

• Circuit paths must not be directly adjacent to walls. The steeper the wall, the greater the distance from the track should be. At a wall inclination of 45° a distance of 150 µm has been tried and tested, as has a wall inclination of 70° and distance of 250 µm

To facilitate the work of developers, LPKF provides a direct LDS interface in the MID module of NEXTRA. With this, 3D injection mold-

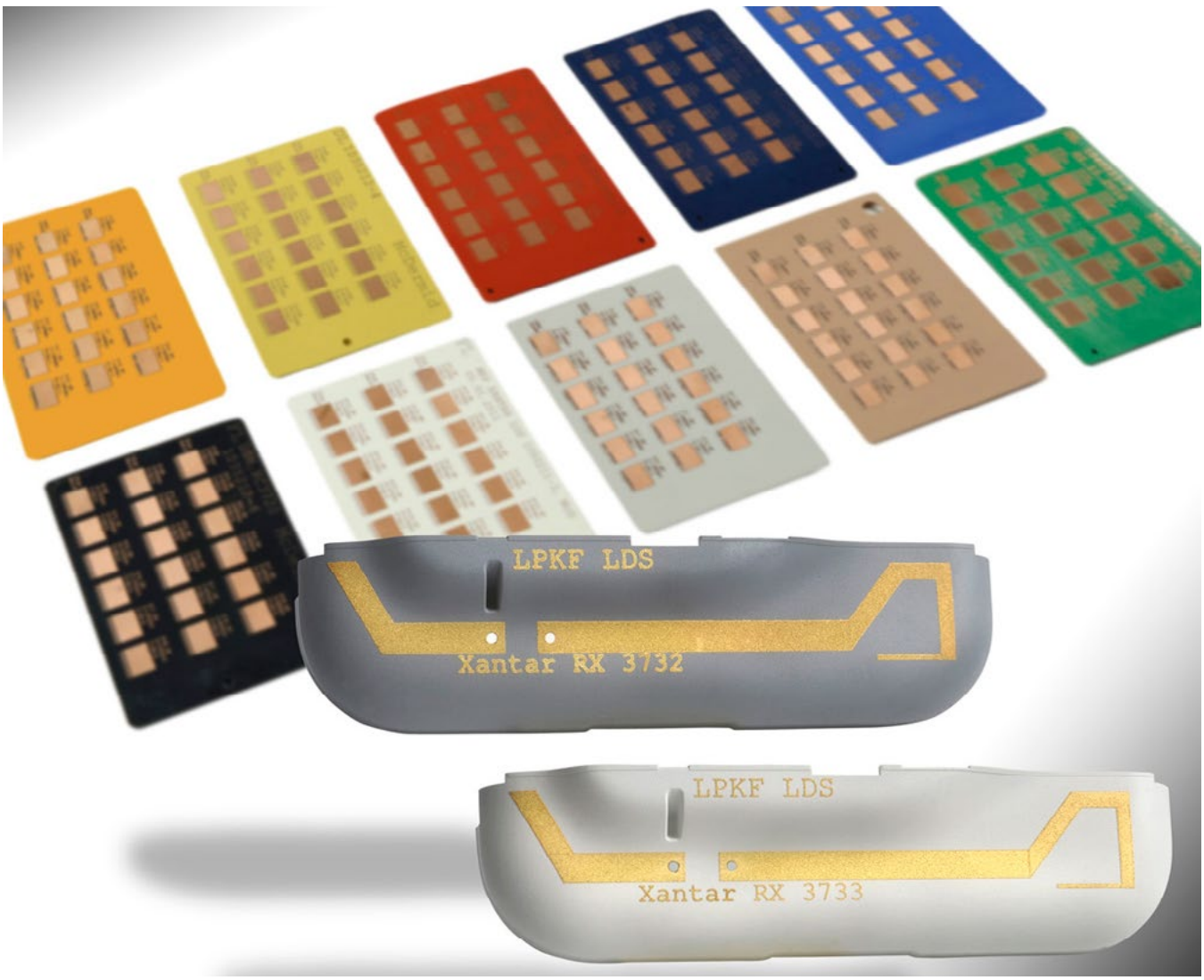

Figure 8: Colorful world of LDS using Xantar LDS from Mitsubishi Engineering Plastics (Source: MEPPR008, MEP).

ed bodies can be designed comfortably and equipped virtually with strip conductors and electronic components[1].

LDS prototyping

Between the layout of an MID part and series production there are several prototype stages —assembly studies or, more generally, to accelerate product development. Serial production prototyping had, until now, been either expensive or impossible. The two-component process, for example, requires expensive injection molding tools. Other technologies were limited to milled bodies or components produced by vacuum casting.

In generative manufacturing processed parts are generated layer by layer directly from CAD data and without the use of forming tools. The most important procedures are fused deposition modeling (FDM), selective laser sintering (SLS) and stereolithography (SLA). The range of plastics available for the different process technologies is expanding. Developers can therefore obtain MID prototypes with characteristics that are already optimized for later use.

The LDS prototyping presented by LPKF at the productronica 2013 was based on a special lacquer. It is used to coat the surface of a plastic body created by rapid prototyping. LDS laser-activatable additives are incorporated in the

Figure 9: After building up a body in rapid prototyping it is painted with ProtoPaint LDS. The laser transmits the projected circuit structures and metal layers are built up using an electroless bath.

lacquer LPKF ProtoPaint LDS. It is available as a simple spray can. This paint can coat almost any plastic surface with a laser-activatable coating.

LPKF ProtoPaint LDS considerably accelerates the prototyping of mechatronic components in conjunction with modern generative manufacturing processes. First, a blank is made and varnished with a layer thickness of about 30–40 µm. Very often, one step is sufficient for a homogeneous layer. The lacquer has to be hardened in an oven for approximately three hours. Afterwards, this component can be structured like a series part. The adhesive strength of the conductors after metallization is similar to plastic components made of LDS plastic.

The last step in the prototyping process is to metallize the plastic parts. In collaboration with Enthone GmbH, LPKF has developed a very simple solution: LPKF ProtoPlate LDS is a copper bath, which can be used without any prior chemical knowledge. Just put the copper bath into a beaker, heat it up to 42°C, add a vial of activator and put the structured parts into the bath. It is active for approximately two hours and can build up platings with a thickness between 3 µm and 10 µm.

This fully developed prototyping process fully closes the gap between layout and series production. It becomes very comfortable, quick

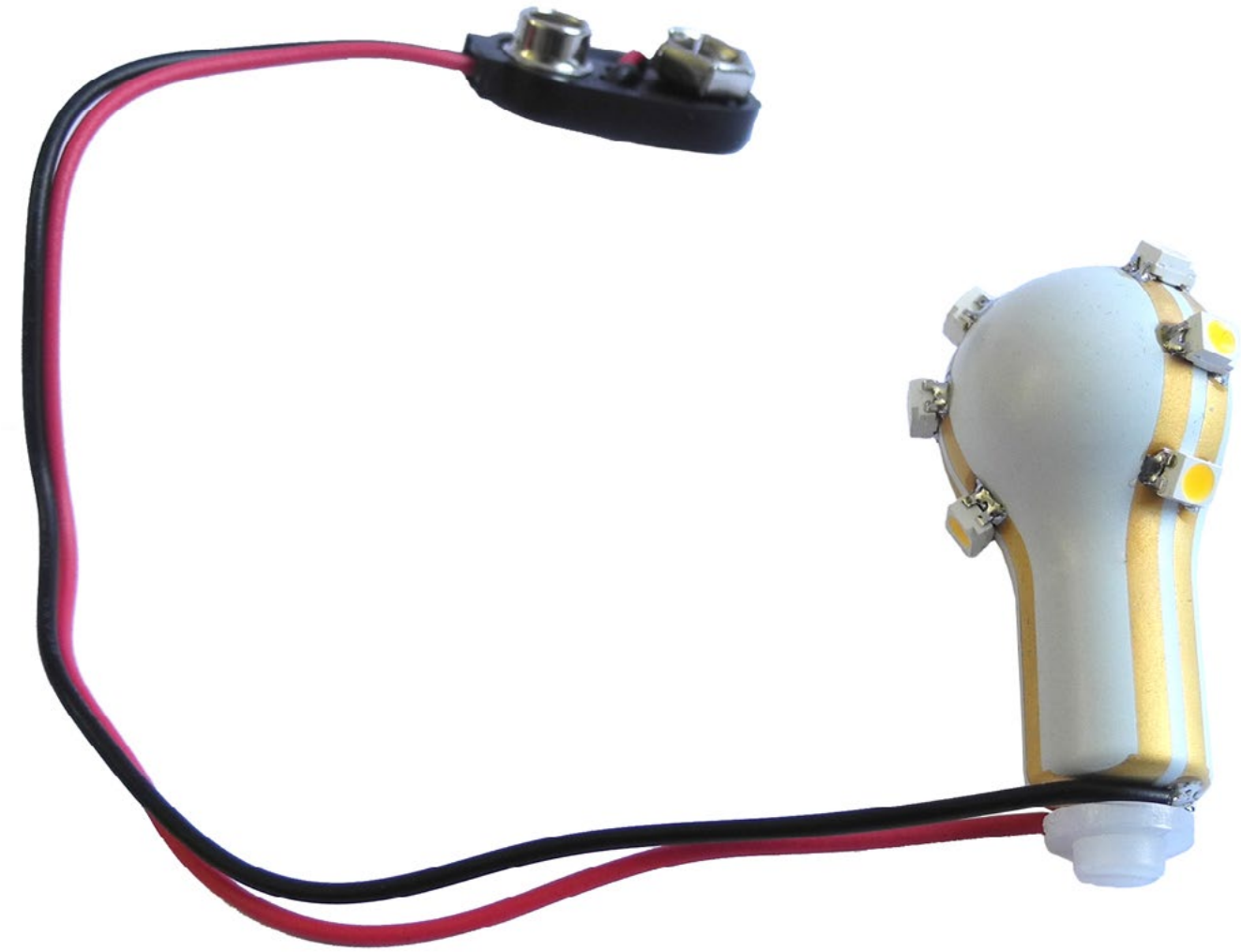

Figure 10: LEDs on a metal body, covered with LDS PowderCoating, etched by a 3D laser system, and metalized in a metallization bath.

and economical and uses the same technology as the mass production to follow.

Circuitry on Metal Parts

With two versions of an LDS-capable powder coating, three-dimensional metal parts can be turned into circuit carriers. New product layout possibilities enable any spatial arrangement of LEDs and offer good thermal properties, opening up opportunities for fields such as production of LED lights with the LDS powder coating.

With LPKF LDS PowderCoating, a metal base substrate, not an LDS plastic, is coated. Powder coating is ideal for metal surfaces such as steel or aluminum, but also works on electrically conductive plastics. The powder is applied in an electrostatic process, which guarantees a homogeneous coating of precisely controllable thickness.

The metal substrates assume mechanical functions, aid in heat dissipation, and serve as contacts for the electronic parts applied to them. The coated metal parts can be laser-structured and metallized in the same way that plastic parts are.

Powder Coatings: Two Versions

Two versions of LPFK LDS PowderCoating—PES 200 and PU 100—are available. The satin PES surface has been optimized for high mechanical stability, whereas the glossy PU 100 features more robust chemical and thermal properties. At the minimum coating thicknesses of approximately 80 µm and 60 µm, the two powders offer good dielectric strengths when tested using AC voltages greater than 4 kV. To ensure mechanical stability and adhesion there should be a minimum corner radius of 2 mm when PU 100 is used. The adhesion strength of the electronic components on the traces is 90–120 N, similar to the values found in FR-4 and other conventional circuit boards.

PU 100 is approved for soldering for a duration of five seconds at 270°C, whereas PES 200 is limited to 240°C for the same period. According to the results of preliminary tests, PU 100 is suitable for V-0 (UL-94) certification. Applications for certification have been submitted for both materials.

Both powder coatings are available in 2 kg (test sample) and 20 kg (series production) containers. LDS PowderCoating is neither a dangerous good nor a hazardous material and can be processed like a conventional powder coating product. **PCB**

References

1. Design rules are available for free download at www.lpkf.com.

Malte Borges is the press officer of product communication at LPKF.

3D Printers Create Custom Medical Implants

A team of researchers at Louisiana Tech University has developed an innovative method for using affordable, consumer-grade 3D printers and materials to fabricate custom medical implants that can contain antibacterial and chemotherapeutic compounds for targeted drug delivery.

The team from Louisiana Tech's biomedical engineering and nanosystems engineering programs collaborated to create filament extruders that can make medical-quality 3D printing filaments. Creating these filaments is a new concept that can result in smart drug delivering medical implants or catheters.

"After identifying the usefulness of the 3D printers, we realized there was an opportunity for rapid prototyping using this fabrication method," said Jeffery Weisman, a doctoral student in Louisiana Tech's biomedical engineering program. "Through the addition of nanoparticles and/or other additives, this technology becomes much more viable using a common 3D printing material that is already biocompatible. The material can be loaded with antibiotics or other medicinal compounds, and the implant can be naturally broken down by the body over time."

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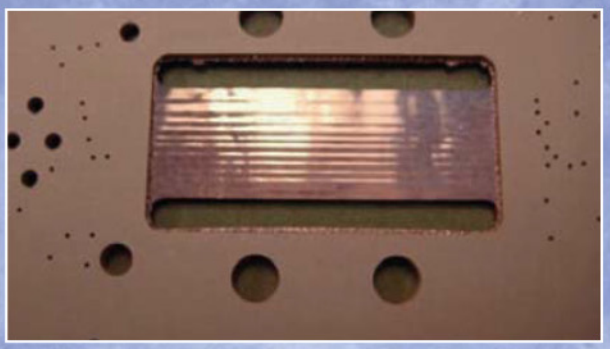

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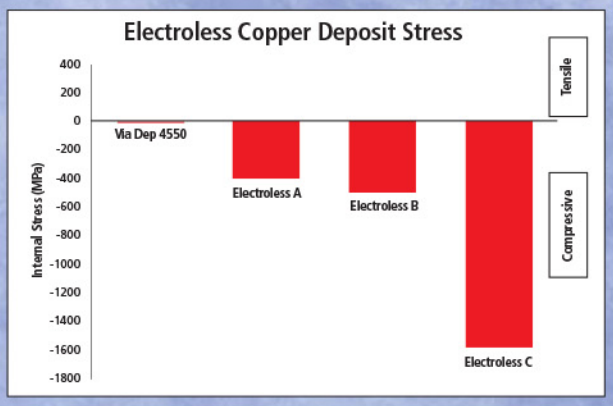

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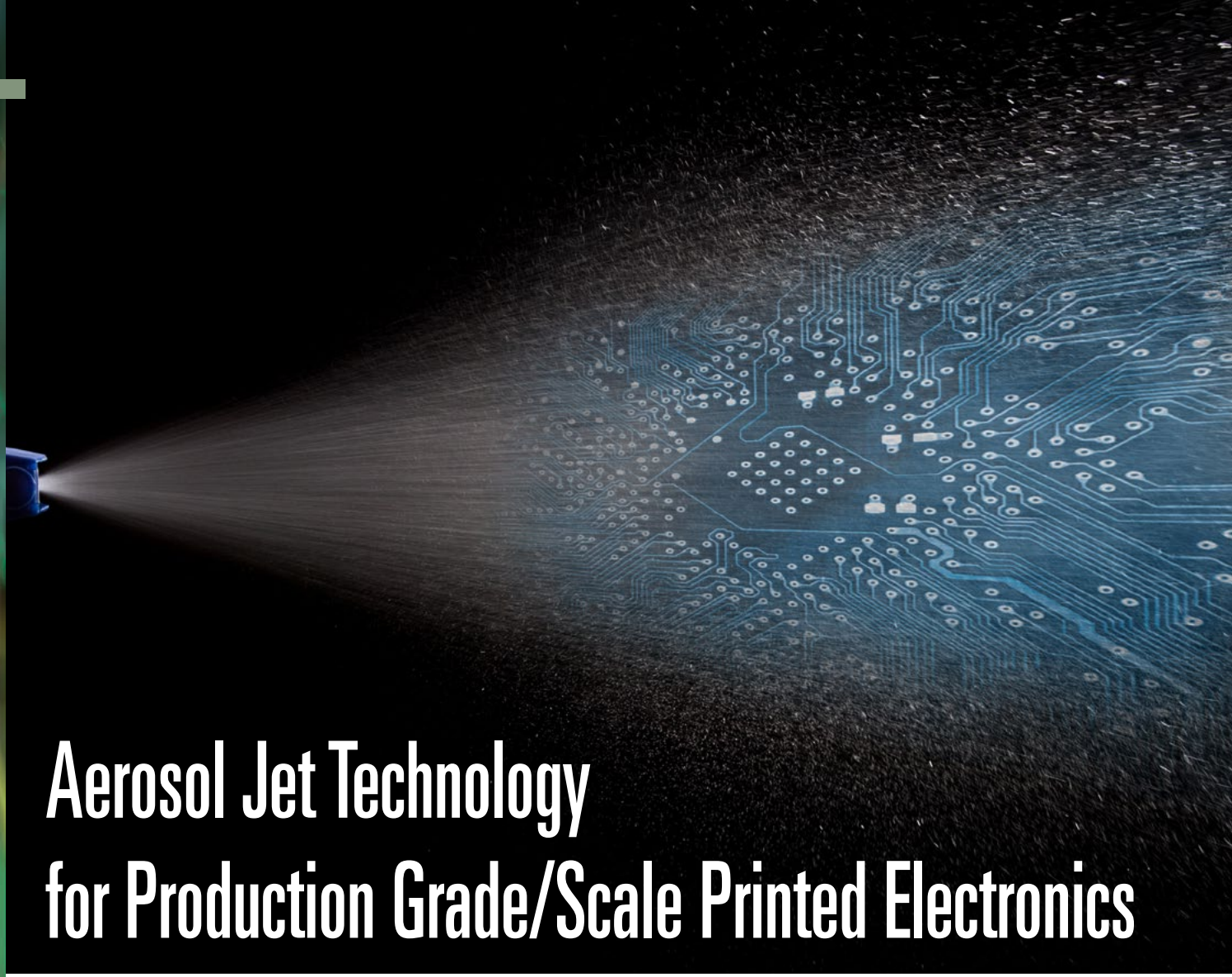

Aerosol Jet Technology for Production Grade/Scale Printed Electronics

by Ken Vartanian
OPTOMEC

Although printing techniques such as screen-printing have long been used to produce portions of an electronic system, such as conductive traces, solder masks, or component silk screens on a circuit board, the term printed electronics (PE) generally refers to more recent developments where common low-cost graphics printing technologies are applied to the production of the various elements of an electronic end-product. These include gravure, flexography, ink jet, aerosol jet, etc.

While traditional electronic products are the current beneficiaries of PE, a new generation of smart devices with integrated sensors and antennas enabling the Internet of Things hold even greater potential for widespread adoption. For example, printed strain gauges that conform to the critical surface areas will measure stresses and initiate corrective action before catastrophic failure. This new generation of intelligent devices will require new manufacturing methods that can closely couple electronics onto mechanical structures.

Evolution of PE

In its original vision, PE presumed that the entirety of fairly complex end-products (e.g., solar cell, display, smart card, etc.) would be produced solely with printing technologies. But in reality commercial success to date has been limited to fairly simple, and in some cases novelty, products (e.g., greeting cards, signage, RFID, etc.).

This has caused some suppliers to take a more pragmatic view and leverage the benefits of printed electronics initially as a point solution that can add value to existing manufactur-

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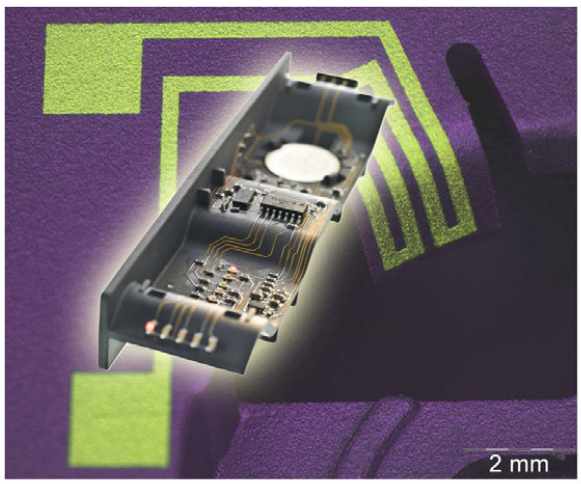

MID and 3D – the path to growth is clear!

MID is the abbreviation for "Molded Interconnect Device." The goal of MID technology is to unite electrical and mechanical functions in a single construction unit. The circuit tracks are integrated into the housing, enabling the reduction of weight and space, and are more eco-friendly than conventional PCBs.

The technology is currently most popular in vehicle electronics and telecommunications, and the number of these components available on the market is growing markedly. As a result, MIDs are increasingly being integrated into computers, household appliances and even into medical technology.

Vapor Phase Soldering offers an exciting alternative to the intricate processes commonly employed to create the connections between assembled components and the substrate.

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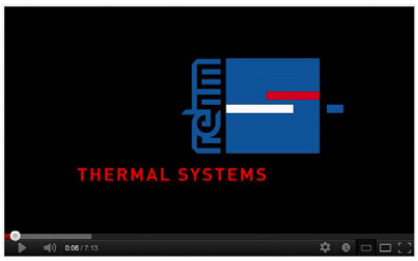

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ing lines and existing commercial products. For example:

- Solar cell: replace screen-printing to reduce the size of collector lines
- Display: replace photolithography to lower cost of jumper circuits
- Smartcard: replace wirebond to produce robust conformal interconnects

While implementations such as these are gaining traction with industry, the pace of more widespread adoption has been slowed by many factors, including risk aversion to replacing entrenched solutions, limited availability of low-cost electronic inks, and the lack of reliable high-volume systems for printing electronics.

Moving Toward Production-Grade Solutions

However, there are many PE projects that are far down the path in terms of development and deployment, and it is fair to expect that 2015 will begin to see the rollout of PE solutions as a key element of mass production of high-volume consumer end-products, most notably in the smartphone and tablet space.

And, while PE has a long way to go to realize the vision of implementing an entire complex end-product, the technology has shown the potential to contribute to the manufacture of many of its constituent elements in the foreseeable future.

For example, Optomec, the inventors of the patented Aerosol Jet printing technology, has active projects printing the following portions of a smartphone:

- 3D antennas onto the back cover case
- Edge circuits for the display
- Jumper circuits for the touch screen
- 3D interconnects for the chips
- <50 micron underfill dispense for increased board density

Printing Technologies—Aerosol Jet

The Optomec Aerosol Jet technology is a material deposition solution used to directly print functional electronic circuitry and components onto a wide variety of planar and non-planar substrates, without the need for masks, screens or subtractive post-processing. The process utilizes an innovative aerodynamic focusing technique to collimate a dense mist of material-laden micro droplets into a tightly controlled beam that can produce features as small as 10 microns or as large as 1+ centimeter in a single pass. Coupled with a motion control system that moves either the head or the substrate, high resolution patterns can be created to produce electronic and physical structures, as well as wide area conformal coatings.

Aerosol jet technology is a combination of two separate mechanisms, atomization and deposition, with independent control and operation. These fundamental building blocks are highly flexible in terms of their ability to support both low and high viscosity inks, produce both thin and thick layers, and print both small and large features.

Input

The first step in the process is based on atomization of a liquefied material into a dense mist of micro-droplets ranging from ca. 1–5 micron. Varied mist generation techniques, such as ultrasonic and pneumatic methods, enable the system to support a very broad range of material types and material formulations; e.g., nano-particle inks, conductive polymers, insulators, adhesives, and even biological matter. The mist, or "aerosol", is then propelled by a carrier gas to the aerosol jet print head.

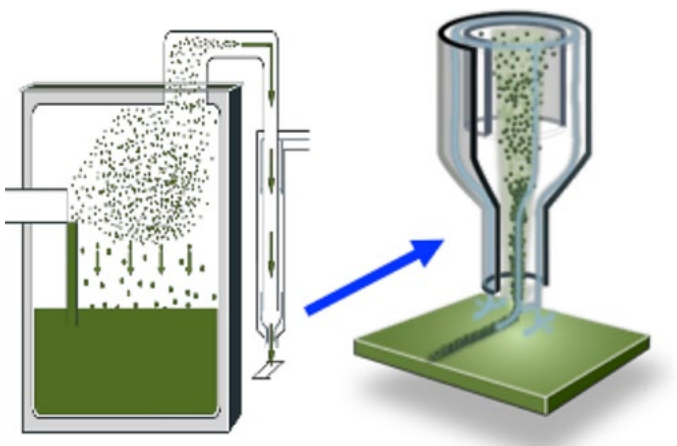

Figure 1: Aerosol jet input (l) and output (r) illustration.

Output

In the print head (deposition mechanism), the aerosol is surrounded on all sides of its flow path by a second gas stream. This "sheath" gas compresses the mist towards the center-line, and further directs it towards a focusing nozzle that collimates the aerosol into a precise continuous beam of material, as small as 10 microns wide. The continuous multitude of droplets exit the nozzle at velocities as high as 50 m/s and impact on the substrate, which is moved in the X-, Y-, and Z-axis using CAD/CAM control. Patterns are further defined using a shutter to produce stops and starts.

The aerosol jet approach has a number of advantages including:

- Prints a wide variety of inks, with high solids loading and viscosities up to 1000 cP
- Prints feature sizes ranging from 10 microns to centimeters.
- Prints on low temperature substrates
- Non-contact, conformal printing with high stand-off distances of 1–5 mm
- Prints on textured, non-planar, and 3D surfaces
- Able to mix multiple materials on the fly and print gradient structures
- Scalable for high-volume production application using multiplexing

Materials

The aerosol jet process is capable of handling a wide range of material classes required for manufacturing electronic circuits and components. Some example materials are shown in Figure 2.

Aerosol jet can print deposits on virtually any surface material—polymers, silicon, glass, metals and ceramics. The long focal length of the aerosol jet beam enables conformal printing on irregular and 3D surfaces.

Applications

Applications for PE are as far reaching as electronics themselves. Figure 3 illustrates some of the many aerosol jet applications that are under development by Optomec and its end users, which includes solutions for the semiconductor, display, energy, and life sciences industries. Many of the near-term mass production applications are being driven by the strong demand for smartphones and tablets.

Printed Antennas for Mobile Devices

A new high volume PE process is available that lowers manufacturing costs for antennas used in mobile devices. The process works with standard injection molded plastics—no special additives or coatings are required. Based on aerosol jet technology, the digital process prints conformal antennas using conductive nanoparticle silver inks. The printing process accurately controls the location, geometry and thickness of the deposit and produces a smooth mirror-like surface finish to ensure optimum antenna performance. No plating or environmentally harmful materials are used in the process.

Mobile device antennas for LTE, NFC, GPS, WiFi, WLAN, and BT have been printed using the aerosol jet process and independently tested by a leading cell phone component supplier. Measured antenna performance is comparable to other production methods. The aerosol jet printing process is scalable: antennas can be

Conductive Metals	*Nano-particle Ag, Au, Pt, Pd*
Conductive Polymers	*PEDOT, Carbon Nano Tubes*
Semi-conductors	*P3HT, PQT, CNTs*
Resistors	*Carbon, Metal Oxides*
Dielectrics	*Epoxy, Acrylic, PMMA, Polyimide, PTFE*
Biologic Materials	*PLGA, DNA, Proteins*

Figure 2: Partial list of aerosol jet materials used for printed electronics applications.

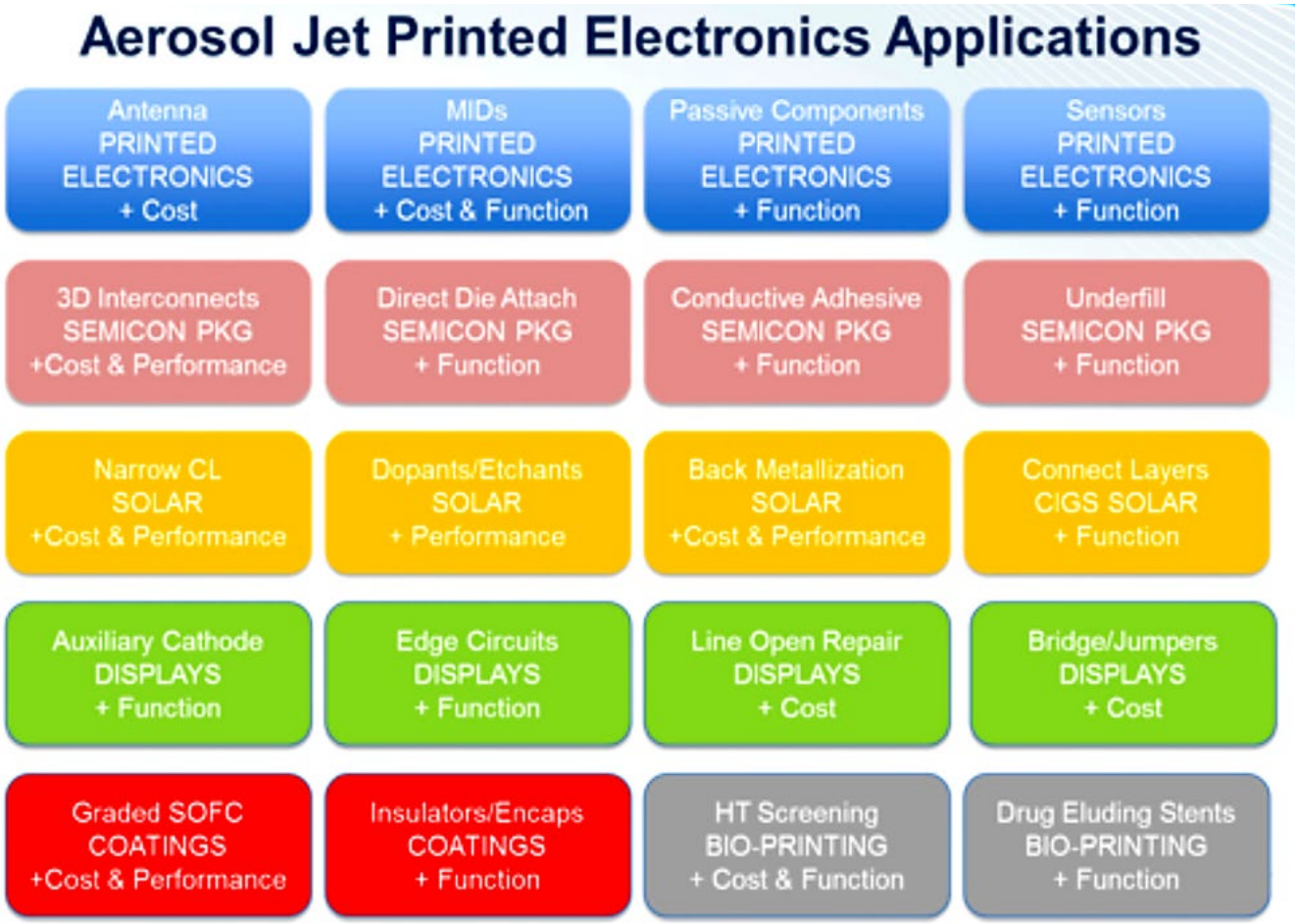

Figure 3: Aerosol jet printed electronics applications in development.

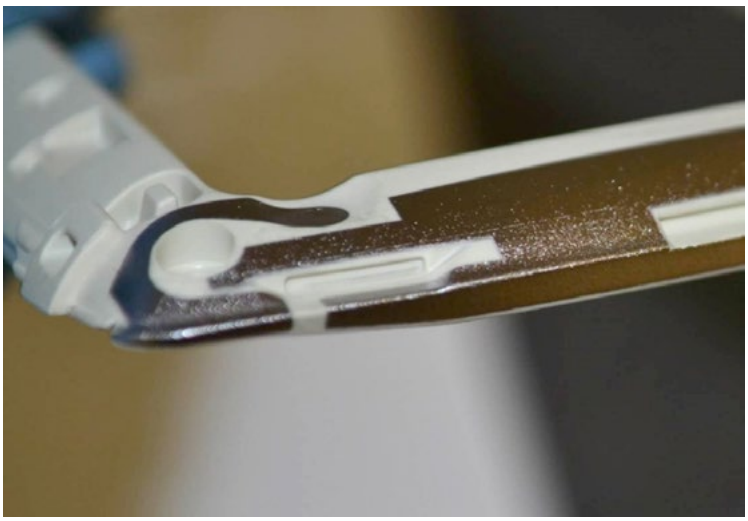

Figure 4a: 3D Main Antenna printed on cell phone insert.

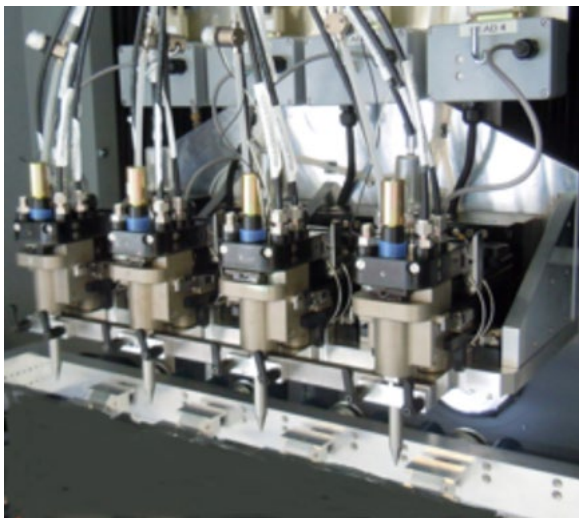

Figure 4b: Aerosol Jet quad production system with 5-axis automation (Courtesy of Neotech AMT GmbH).

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printed on up to four cases simultaneously on a single machine. Machine throughput for a typical size patterns average 30,000–40,000 antennas per week.

Semiconductor Packaging

PE applications for the semiconductor industry can improve product performance and reduce the size of electronic devices. For example, aerosol jet can print 3D conformal traces to interconnect vertically stacked multi-function chips providing a new manufacturing alternative to wire bonding or through silicon via (TSV) technology. The 3D printed interconnects conform to the surface of the die stack making them shorter than wire bonds and thereby improving performance and reducing power consumption (Figure 5). In high-frequency signal processing applications, 3D printed interconnects eliminate well known crosstalk issues experienced with wire bonds.

In another packaging application, a new conductive epoxy material which, when printed with aerosol jet technology, enables ultrafine pitch die and component attach. Syringe based methods, which are commonly used in production today, dispense conductive epoxy dots that are ca. 300 microns in diameter, and can require costly manual clean-up. Aerosol Jet is able to print 50-100 micron dots and pads that are clean and volumetrically consistent (Figures 6 and 7).

Display and Touch Screens

The display industry currently uses aerosol jet for a number of production and repair applications. In one example, Micronics Japan (MJC) developed an enhanced defect repair system for touch panels, LCD, plasma, and e-Paper

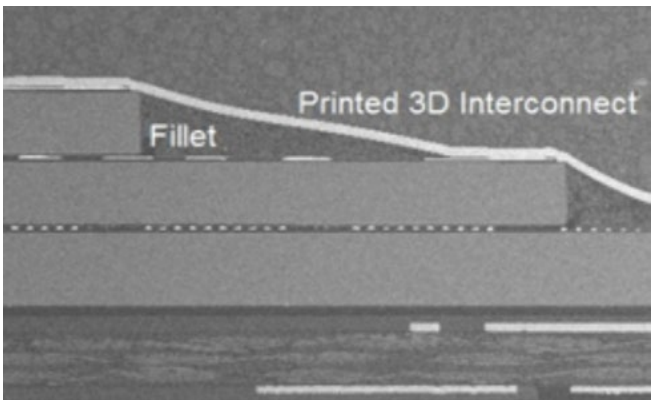


Figure 5: Printed electronics on stacked die.

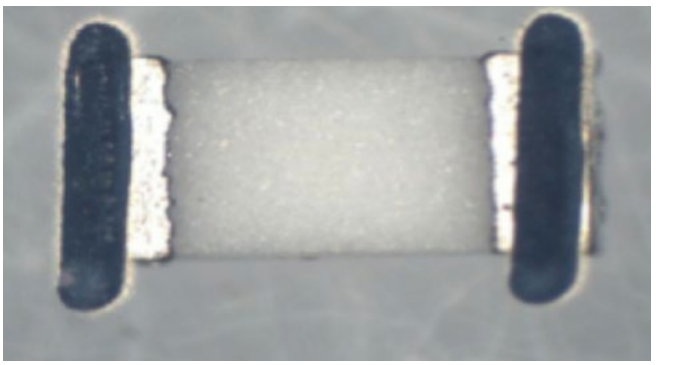


Figure 6: Aerosol Jet printed pads to attach 0603 resistor.

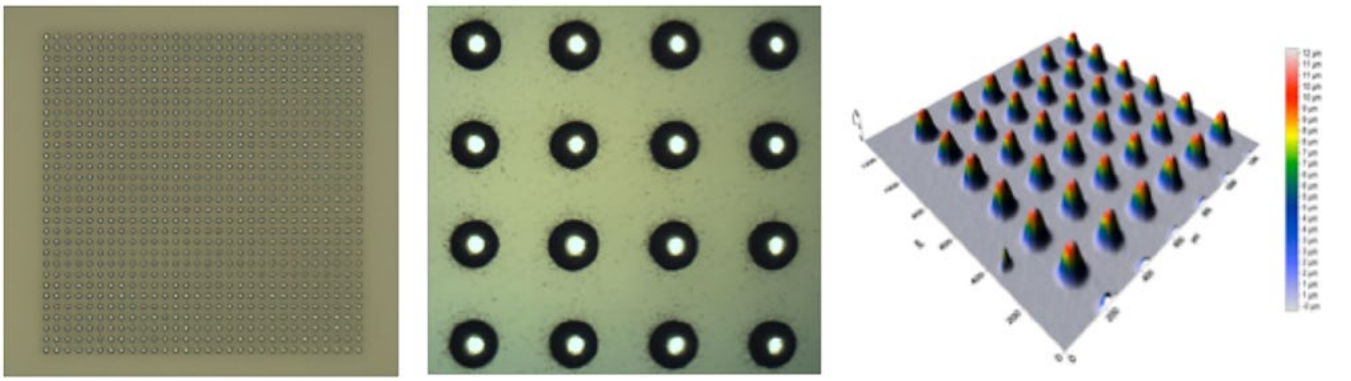


Figure 7: Conductive epoxy dots from 50–100 micron diameter, and 10–25 micron thickness/height printed with aerosol jet. (Scan courtesy of Cyber Technologies.)

display products using aerosol jet printing. The MJC NEOSYS LOR System (Figure 8) improves production yields by repairing open circuits in the display backplane. Since these repairs must be invisible to the human eye, aerosol jet prints conductive lines that average six microns wide to fill the gaps. The system is in production at multiple customer sites and provides 25% higher throughput than alternative repair methods, such as laser chemical vapor deposition (L-CVD).

Other aerosol jet applications in display and touchscreen include:

- Edge Circuits: AJ prints narrower line width to allow increase in active area
- ITO Jumpers: AJ printing is a lower cost alternative
- Conductive Grids: Conductivity booster for ITO layer in OLED displays
- Hermetic Seals: AJ printing is lower cost with higher yield
- Tactile Feedback: AJ fully printed haptic devices

Embedded Components

In an effort to develop a solution for creating intelligent structures that integrate electronics into structural components, Optomec has partnered with Aurora Flight Sciences and Stratasys to fully print a smart wing for an unmanned aerial vehicle (UAV). An Optomec aerosol jet system was used to print a conformal sensor, antenna and LED circuitry directly onto the wing of a UAV that also was fully printed using a Stratasys 3D printer (Figures 9a and 9b). The hybrid printing approach offers the potential to dramatically reduce the weight of the UAV, enabling more payload. Manufacturing will also benefit by simplifying electronic integration, especially for miniaturized products. Field repair can likewise be improved by printing replacement parts on location as needed saving inventory and logistics costs.

In related work, Neotech Services utilized aerosol jet to print a fill level sensor and control circuitry directly on the side walls of a dual chamber plastic tank (Figure 10). As the fluid level in one of the chambers increases, the printed capacitive sensor signals the pump to

Figure 8: NEOSYS repair system with Aerosol Jet printing. (Photo courtesy of MJC)

Figure 9a: Printed signal circuit powering flashing LEDS.

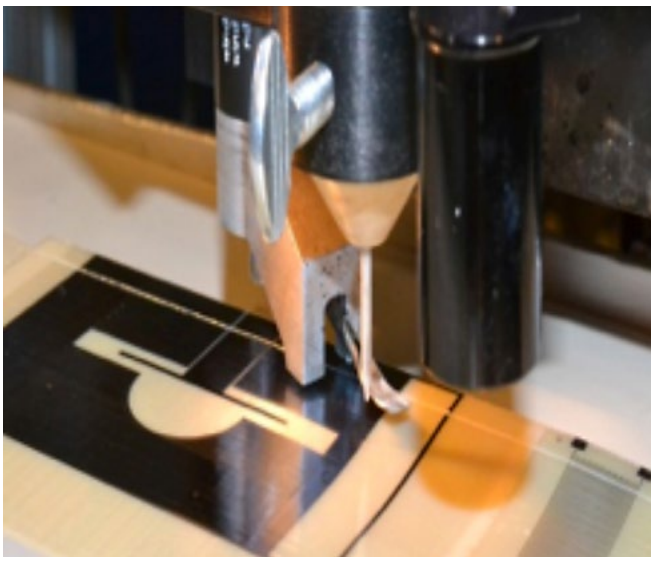


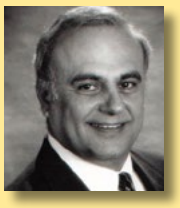
Figure 9b: Printed RF antenna transmitting live video.

Figure 10: Dual chamber tank with aerosol jet printed sensor and control circuits.

reverse direction. The printed circuits also drive LED fill level indicators which were mounted and electrically connected to the control circuits using an aerosol jet printed conductive epoxy. The project was funded by the Bavarian Research Foundation.

Summary

Printed electronics is emerging as viable and advantageous approach to manufacture a wide range of electronics components. Initially spurred on by the mobile revolution of smartphones and tablets, PE is now being eyed as a key enabler of a new breed of ubiquitous sensing and monitoring devices behind the Internet of Things. While conventional manufacturing methods work well when used to produce electronics on rigid 2D substrates, PE is a promising approach to address high-volume production of tightly integrated 3D electromechanical devices to reduce size, weight, and increase functional capabilities. **PCB**



Ken Vartanian is vice president of manufacturing at Optomec.

VIDEO INTERVIEW

Advanced West Acquires Dryer Manufacturer Comac

by Real Time with...IPC APEX EXPO 2014

Advanced West Founder Brian Solo discusses his background in the business, Advanced West's area of specialization and the company's quarter-century in business, including the recent purchase of Comac Engineering, established in 1983.

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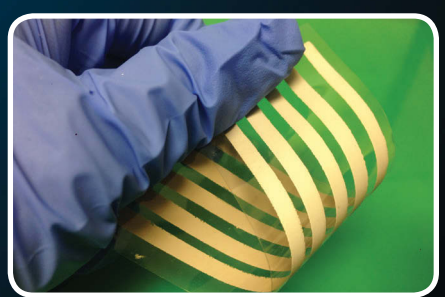

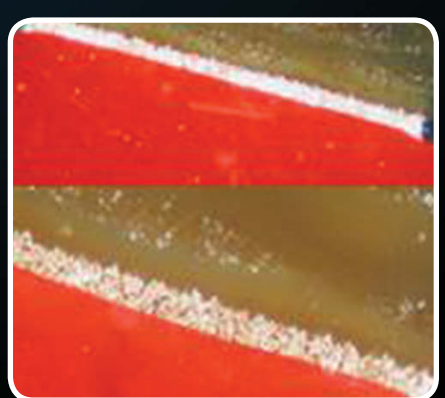

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FIELD NOTES

Making the Impossible Possible

by Judy Warner
TRANSLINE TECHNOLOGY

2014 IPC APEX Newcomer

If you had the good fortune to attend IPC APEX EXPO in Las Vegas earlier this year, you probably caught wind of a newcomer among us. eSurface Technologies burst onto the scene at the Mandalay Bay Convention Center with as much subtlety as a small herd of elephants. They came holding the keys to the promised land clenched firmly in their fists: A viable additive technology for the PCB industry. This technology garnered favorable reviews from several persons of note on IPC's leadership team (among others), some of whom had already witnessed live demos before the show. While my curiosities were piqued, my time in Vegas was too brief to learn all that I wanted to about this new kid on the block.

Coincidentally, immediately following IPC APEX EXPO, an article of mine was published in the April issue of *The PCB Magazine*. In the article, I bemoaned the shortcomings of print-and-etch technology when it came to boards requiring high speed and miniaturization. I concluded that we were "ripe for a breakthrough." Little did I know, when writing that article, that eSurface was about to unveil just such a technology.

Since our company, Transline Technology, specializes in RF and microwave bare board applications, we are keenly aware of the woes of engineers in this field. This made eSurface claims of keen interest to me. So, I reached out to the company to learn more about their technology and what it may mean for our industry. Since then, I have spent a couple of months diving in and learning all I can about the technology. I've also had the privilege to meet with all the key leaders of the company and have asked innumerable questions. Now I have the opportunity to share what I've learned with you.

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Cupracid AC – High Speed Conformal Plating for Vertical Conveyorized Systems

Cupracid AC at 3 A/dm²
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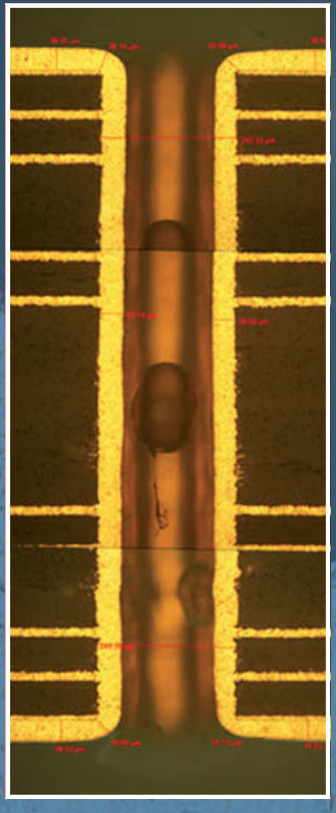

Cupracid AC at 3 A/dm²
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Throwing power
>90 % min

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ATOTECH

What is eSurface?

eSurface is an additive (or embedded) process that may change the way many circuit boards are manufactured—particularly HDI boards and high-performance boards that are built for speed and require the highest levels of signal integrity. The inventor of eSurface is Dr. William Wismann. He developed a liquid covalent bond that reduces over a dozen steps of current subtractive technology, down to these three steps:

- eSurface covalent bond is applied directly to unclad substrate
- The coated panel goes directly into a standard or LDI photo imaging unit, followed by a water rinse and dry
- The panel then goes directly into an electroless-plating tank

The first and most obvious benefit of eSurface is that it eliminates processes. No dry-film photo resist, no more developing solution, no more plating conditioners, etchants or waste treatment—making it cheaper, environmentally friendly, and capable of trace widths down to 1–2 mils, while offering increased yields. Cheaper, faster, smaller, cleaner; it's a PCB fabricator's dream!

Additive or Embedded?

After watching several live demos of the eSurface process at their lab in Carlsbad, California, and after looking at multiple panels under a high-powered microscope on a huge monitor, I understand why the leaders at eSurface hesitate to call this an additive process. It needs its own category, due to the fact that the chemistry is absorbed into the pores of the substrate and the copper displaces the chemistry there, embedding it (at an atomic and microscopic level) and causing the substrate and copper to share electrons, thereby locking the metal in place. What this means practically is that the peel strength is outstanding—far better than panels laminated with copper foil from substrate manufacturers. Furthermore, even if we could reliably produce 1–2 mil traces through current print and etch technology, the fragile traces are easily wiped away with a brush of your hand. There's simply not enough adhesive left beneath that trace to hold it securely in place. I cringed when Vice President of Strategic Operations Alex Richardson took a car key to a 1mil trace—and then I was stunned to see it remain fully intact! Though the trace was understandably marred, the trace was unmoved.

So far, I have explained how eSurface has made the impossible possible by offering the following:

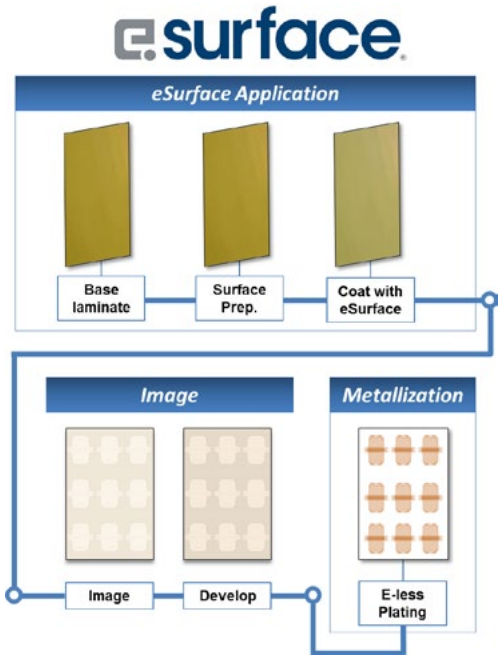
- Chemistry that enables direct imaging and plating to bare substrates while eliminating the side effects of etching (such as over or under-etching and inconsistent trace geometries)
- The elimination of multiple process steps that save time and money
- The ability to offer HDI and robust fine features, with relative ease and cost-effectiveness for the first time in our industry's history
- Unprecedented bond/peel strength
- Water-soluble chemistry that can go right down city drains, offering us an environmentally friendly solution for our customers and ourselves

In addition to:

- Traces, pads, and holes are plated simultaneously offering homogenous plating surfaces, which eliminate many issues that arise from the current 2-step plating process—particularly around the hole-knee
- Any electroless metal can be plated directly to the substrate (i.e., copper, silver, tin or gold)
- Nearly all capital equipment required is already present in most PCB facilities. The only additions needed are two retrofit pieces of equipment from Chemcut and Austin American, which are relatively minor investments
- Conductor and feature geometries that are pristinely crisp and consistent and will certainly offer better signal integrity
- 3D products and features that can now be easily printed and plated. We are no longer limited to planar, 2D surfaces

Too Good to be True?

If you've been around the PCB industry for as long as I have, you know that if something sounds too good to be true, it usually is! We've seen a couple of hopeful additive processes come along in the past 30 years or so, and they fizzled out as quickly as they came. As a result, many have a crusty cynicism that has lingered because of the failed promises of the past. Quite frankly, I've been trying to shoot holes in the eSurface technology for a while now with little to no success. There are only two potential limitations I see thus far—and they don't appear to be deal-breakers. The first is that using the eSurface covalent bond and electroless copper only allows you to plate up to a maximum of a half-ounce of copper. Of course, if you are plating fine features, this is more than enough copper because the ratio of the width and height of a trace. If you want more copper, you can flood the panel with copper, after the eSurface build up, and then use regular print-and-etch on top of the eSurface layer. This is considered a semi-additive solution which stills works extremely well.



The second issue is related to aspect ratio. On a very thick board, it is difficult to fully flood the inside of the hole-wall with light for photo exposure. Any surface not exposed with light could result in voids. Again, a simple solution is to simply photo print one side at a time so the hole-wall gets fully exposed.

A Unique Model

When faced with the decision to be an intellectual property company or a chemical company, eSurface chose to be the former. This means they are going to license the technology to PCB manufacturers, handing over their IP and letting the innovators in our industry develop applications that have not yet been dreamed of. The technology has so shattered the mold of how boards can be made that it may enable untold innovations within the electronics industry. However, this is the PCB industry, and we have survived a decimation of our industry in this country and continue to white-knuckle every ounce of business we have. We don't like licenses, or ambiguities, and innovation seems too risky when we are operating on razor-thin margins. In short—risk is too risky! In my opinion, this is the one thing that is slowing adoption of eSurface. As part of our due diligence here at Transline, I am working on two things that will hopefully offer some concrete data. I am having some microwave test structures designed and will run side-by-side samples of eSurface with print-and-etch samples. Afterward, we will measure performance and physical geometries, which will give us some actual data to support eSurface claims. Secondly, we are awaiting data to support real-world cost savings in a commercial environment. Additionally, much testing is taking place at the eSurface lab and, over time, we will certainly see the results of that work. I will certainly share these results with you, as they become available.

The Future of eSurface

An eSurface line has been in place since January 2014 at one PCB shop in Silicon Valley. Since the installation of eSurface, yields have risen sharply and dramatically. The owner commented that, after a few short days, they were able to produce the "best boards they have ever made." On one particularly challenging design with very fine lines, the yields went from under 17% to approximately 90%.

Transline Technology is currently evaluating eSurface; the leaders of our company are in the end stages of their evaluation process now. Dozens of other PCB manufacturers in California and across North America are in varying stages of evaluation or adoption and installation. Concurrently, Japan is quickly and eagerly adopting the technology due to the high demand for

HDI in their marketplace. Large OEMs in North America and Japan are also eagerly grasping at this technology and quickly integrating it into their approved process controls. This means that once manufacturers install eSurface lines, there will be immediate opportunities for business. Beyond the PCB industry, there are immediate applications for semiconductor companies who are courting eSurface heavily.

The Elephant in the Room: China

One of my earliest questions for eSurface leaders was, "Are you taking this to China?"Of course they are; they would be foolish business people if they didn't! However, they are going to keep China waiting for approximately two years. This gives us a head start for the first time in decades. If eSurface cost-modeling is even remotely accurate, we could potentially bring back work to our shores during this time period. It also allows us a window of time for development for unprecedented innovation that effectively puts us light years ahead of our Asian competitors. The possibilities are exciting to consider!

eSurface Advisory Board

In addition to eSurface's impressive leadership team, they have wisely added an advisory board that represents a broad spectrum of industry experts with whom to consult regarding nuances of inter-industry needs, concerns and objectives. Due to my long tenure in the industry, as well as my unique focus on issues surrounding the RF and microwave industry, eSurface has invited me to join the ranks of their advisory board. I have humbly and gladly accepted, and look forward to working directly with eSurface to consult, learn and collaborate with their team to help meet the needs of our industry.

Hope Floats

For some time now the PCB industry has been a zero-sum game. If I win some new business, you lose some. We just recycle existing PCB business while semiconductor companies continue to innovate and have all the fun. Because of that lopsided reality, we find ourselves pinned in the corner with one inadequate tool in our toolbox: subtractive technology. But what if a truly viable additive process has been discovered? What if we could keep pace with the innovation of our semiconductor counterparts? What if we could offer robust 1–2 mil lines consistently and reliably? What if we could offer pristine feature geometries that aid in excellent signal integrity? What if under- and over-etching was a thing of the past and consistent geometries were possible? What if we could offer significant cost savings, making us domestically and globally competitive for the first time in decades? While I must carefully and responsibly examine and prove out the claims of eSurface, I must not be categorically dismissive or industry-hardened. I must open my mind to the possibilities that eSurface puts before us, and when the litmus tests are passed be ready to fully embrace the excitement of a hopeful future for our beloved industry! **PCB**

Judy Warner is the director of sales and marketing for Transline Technology, a PCB manufacturer specializing in RF and microwave applications in Anaheim, California. To contact Warner, or to read past columns, click here.

Murrietta, eSurface Ink Technology Licensing Agreement

Related news from PCB007.com:

eSurface Technologies, the developer of the eSurface proprietary method for creating printed circuit boards, today announced the completion of a technology licensing agreement with Southern California-based Murrietta Circuits, one of the preeminent circuit board providers in North America.

The executed technology license agreement between Murrietta Circuits and eSurface Technologies provides Murrietta the right to manufacture printed circuit boards using eSurface's

patented technology, receive implementation and marketing support from eSurface and to be acknowledged as an eSurface Authorized Facility. The term of the eSurface technology license is five years.

Murrietta's Integrated Solution:

As a Vertically Integrated Electronic Manufacturing Services Company, Murrietta Circuits provides custom made, high-reliability circuit boards for the military, aerospace, and medical industries. A uniquely integrated solution, Murrietta provides design, fabrication, assembly and test services for a true one-stop, turnkey experience.

"We are very excited about this agreement and partnership with eSurface, as we truly believe that this technology will not only change the way that boards are manufactured, but change the way boards are designed, for us and the entire industry," stated CEO Andrew Murrietta. "We spent the last 30-plus years designing and manufacturing circuit boards, so we felt we had a well-honed perspective on what this means for the entire circuit board development cycle. BGA technology and density is driving much of today's biggest challenges within our industry and eSurface gives us that very rare ability to increase circuit density while decreasing cost! Given our business model, we believe we can prove out this process, design in its key advantages and bring products to market faster and more efficiently than anyone."

"We are honored to be able to license the eSurface technology to a manufacturer of the quality and high standards of Murrietta Circuits," stated eSurface Chairman and President, Dave Benson "If we could hand-pick the facility in which we would like to implement our technology, Murrietta would be at the top of that list. We are particularly excited to engage the design expertise of Murrietta to infuse the features and benefits of eSurface into the high-reliability circuit space." **PCB**

VIDEO INTERVIEW

OEM Press Systems Has New CEO, New Technology

by Real Time with...IPC APEX EXPO 2014

Mary Quinlan, Sales Manager, and Rob Henderson, CEO, of OEM Press Systems discuss new technological capabilities in the form of OEM Next Generation. Also, a new arrangement with a group of investors from the composite industry, who have an innovative new product, has OEM poised for a growth spurt.

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PCB007 Supplier/New Product News Highlights

Isola Intros Free Impedance & Power-handling Calculator

Isola is pleased to announce a free impedance and power-handling calculator that predicts the design attributes for microstrips and striplines based on the design's target impedance and dielectric properties of the company's RF, microwave, and millimeter-wave laminate materials.

Qdos Invests in Orbotech Paragon Ultra LDI System

Orbotech Ltd., a global technology leader in solutions for PCBs and IC substrates, announced that Qdos (Malaysia), a Suiwah Corporation company, has purchased Orbotech's Paragon™-Ultra laser direct imaging (LDI) system. Paragon-Ultra LDI systems deliver the highest imaging accuracy and yields to meet the increasing demands of the fast-growing QFN, FC, and BGA packaging segment.

Alpha Circuits Completes Install of NTO HASL Machine

Alpha Circuit President Yash Sutariya states, "The new operating system and mechanical upgrades of the NTO system over our previous supplier's HASL system made this machine our top choice. The uniformity of the solder rivals that coming from a horizontal HASL process."

Insulectro Realigns Execs to Focus on PCB, PE Markets

Insulectro, a leading distributor of materials for use in the PCB industry, has announced changes to its strategic focus on both the PCB and printed electronics markets as two veteran executives take on new responsibilities.

Orbotech Finalizes Acquisition of SPTS Technologies

"We are commencing our relationship with SPTS with great enthusiasm and anticipation," said Asher Levy, CEO of Orbotech Ltd. "We look forward to working with the outstanding SPTS team and combining the extensive know-how and core assets of both companies to further enhance Orbotech's portfolio and industry leadership."

ASC Installs Customized Sputtering Unit for Advanced PCBs

American Standard Circuits has installed a new customized sputtering unit for making advanced PCBs that employ light-weight aluminum heat sinks in hostile and high-temperature environments. PCBs used in defense, aerospace, and deep space telecommunication most often use aluminum as a heat sink due to its light weight and easy machinability.

Rogers Unveils ROG Mobile App, Access to Calculator

The new app allows users to access Rogers' calculators, including the popular MWI (microwave impedance) simulation tool, literature, technical papers, and offers the ability to order samples on the go with smartphones and tablets.

Orbotech: Strong Q2 Results; PCB Segment Recovers

"We are pleased to report strong results for the second quarter. Our PCB business picked up as expected and our FPD business enjoyed another quarter of solid orders as we recorded a cumulative total of $130 million in bookings for the first half of 2014," says Asher Levy, CEO.

Rogers Updates Guidance for Q2; Expects Record Sales

Rogers now expects that it will report all-time quarterly record net sales from continuing operations of $153.5 million for the period as compared to the April 29, 2014 guidance of $143 to $148 million.

PCi Invests in Orbotech Direct Legend Ink Printer

The new Orbotech printer is a self-contained direct printer and UV cure unit. It features multiple automated serialization and barcoding options, eliminating manual operations and reducing the opportunity for error. It also scales nomenclature to match the material movement, eradicating nomenclature on pads.

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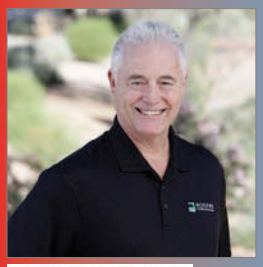

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READER RESPONSE

And the Data Transfer Beat Goes On...

Editor's Note: *Below is the latest entry into the ongoing debate between Ucamco's Karel Tavernier and Mentor Graphics' Julian Coates. Click here to read both sides of the original debate, which ran in our July issue.*

Smart, simple, kind, revolutionary: X2

In a recent article, *Smart Data Formats Automate CAD/CAM* (February 2014), Julian Coates of Mentor Graphics wrote an article about the ODB++ format. My reaction to this, *Gerber—the Smartest Way Forward,* appeared in the July 2014 edition of the same publication, as did a rebuttal by Julian of my article.

Here I would like to rebut Julian's rebuttal of my rebuttal. To be merciful on readers, I will keep it brief, so that the rebuttal process converges rather than spinning out of control.

In Julian's July rebuttal, he wrote: "No doubt Gerber is a very fine format for defining the graphical layers of a PCB."

That's good. My impression was that Julian saw Gerber as an intrinsically error-prone image format whereas I maintain there are very few errors when transferring images in Gerber. So we both agree that Gerber is a very fine image format. Where our opinions diverge is in how we proceed from this fact. In the July rebuttal, Julian went on to state: "At a recent industry debate, he [Karel] suggested that the best way forward is to use Gerber for the graphical data and another format for all the other information that Gerber cannot carry. Thus, he promotes the idea of intelligent, all-encompassing formats for carrying data, but excluding the graphical part. Why reject the advantage of having

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all of that other information linked to the graphical objects as well, and vice-versa? The problem that needs solving is taking all of that fragmented data into a single coherent model comprising both the PCB bareboard and the assembled PCB."

Actually, in no way do I reject the idea of linking all the other information to the graphics objects. On the contrary: It's clear that a PCB is more than a set of images, and all the data describing it must be transferred as a coherent whole. Here, too, we agree. Where we disagree is how we achieve this coherent whole. Julian believes that the wholesale adoption of ODB++ is a practical way forward. I do not. In another passage from his July rebuttal, Julian correctly analyses why ODB++ is not more widely used:

"What limits the implementation of ODB++ more widely? … I would suggest that the reason is not technological; it is a combination of business and human factors. Firstly, it costs money to change a business process; tools have to be upgraded. […] Secondly, there is a perception that continuing to use the old method is not only free but also safe, whereas to use the new method is expensive and uncertain. The safe versus uncertain part is the human part."

These are entirely rational and justified concerns, and clearly the vast majority of this industry feels that they outweigh the benefits of ODB++ (or of any new format that has been tried over the decades for that matter). Who am I to judge that the whole industry is wrong? That said, our industry must move on, and like Julian, I too would like to see CAD to CAM data transfer advance beyond current practices. This is why I propose a path that is far less expensive and risky than that advocated by Julian.

The first step along this path was to clarify areas in the Gerber format specification that were sometimes misunderstood, and to remove elements in it that were outdated, rarely used, or superfluous. This has been carried out in recent years, so the current spec is clear, sharp and to the point—there are no useless bells and whistles in the Gerber format.

The second step, completed earlier this year, was to introduce the Second Extension, or Gerber X2 format. Gerber X2 contains attributes that specify how the layers stack up, identifies via pads, indicates where the impedance controlled tracks are, and describes a host of other parameters that support the image data. With X2, what was missing in Gerber has now been added—in Julian's terminology, the attributes add intelligence to the format. The neat thing is that they do not affect the image, which means that existing workflows are not broken: X2 requires only minimal changes in working practices, and certainly none that would require approval, testing and all the rest. The fully X2-compatible CAD and CAM software will read entire Gerber X2 archives automatically, with all layers in place, while identifying the function of each object. And even in combination with older software that does not support X2, the correct image is still produced. This means that even if users do not reap the full benefits of Gerber X2, they can happily move within the X2 world without problems. Ben Jordan of Altium concurs: "ODB++ is a good standard, but Gerber X2 does solve the problems while being backwardly compatible."

> ***"Who am I to judge that the whole industry is wrong? That said, our industry must move on, and like Julian, I too would like to see CAD to CAM data transfer advance beyond current practices."***

More importantly, this means that nobody is forced to buy anything, and Gerber users can decide in their own time if, how and when to adopt new X2-ready software to take their processes to the next level. For those interested, there is a sample X2 job on the Ucamco download page. It shows the simplicity of the concept. Download it and try it on your own Gerber input software—in all probability you will be able to read in the images correctly, but your software will throw some warnings. This demonstrates the compatibility of X2 with non-supporting software.

Julian makes much of the claim that ODB++ is a single format and that what I propose is a collection of different formats. This underpins his argument that the good old Gerber format should be dumped and replaced with something entirely new. This is a curious argument indeed: ODB++ is in reality a collection of folders with different syntaxes for each type of data, which are all zipped together in a single archive file. In my opinion this is not a showstopper—on the contrary, it's an inevitable consequence of the fact that components, materials, graphics and netlists are all entirely dissimilar objects. They must all be stored in appropriate formats, each of which, by its very nature, is very different from the others. All they have in common is the ODB++ name. This is clearly demonstrated by the following: if ODB++ image input is implemented in your software, it will not miraculously read materials. Even though you may be able to write images, you cannot automatically write a netlist. These are separate items that require individual implementation, each with its own specification, each in its own folder. This is OK; it is impossible to put these intrinsically different objects into the same format. But I fail to see the difference between zipping together a collection of very different ODB++ folders, and zipping together Gerber and IPC-D-356A files. To anyone who might object that 356 is a different format from the Gerber format, I would propose the following thought experiment: Take the 356A specification, tear off the title page and replace it with a page with the title "Gerber Netlist Format." Lo and behold, now, images and netlist are in the same Gerber format! In other words, there's no substance to the claim that ODB++ is a single format—it's all in the name. Of course, in both cases, the information must be consistent. If you offset the netlist to the image, well, you have a problem, both with Gerber and ODB++.

> ***"The beauty of Gerber is that it's simple, and very widely used, and Ucamco's use of attributes is a very clever and straightforward way to improve and build on it."***

What I propose is that we, as an industry, take a practical and pragmatic route to improvement: by keeping what works well, changing what does not and adding what is lacking. With Gerber X2, we are doing just this, as Graphicode's Paul Wells-Edwards points out: "The beauty of Gerber is that it's simple, and very widely used, and Ucamco's use of attributes is a very clever and straightforward way to improve and build on it. By extending the format and making it far clearer, Ucamco has improved the CAM task no end."

Indeed, it makes no sense whatsoever to totally abandon something as good as Gerber's image format, which covers the most difficult and critical part of any PCB data archive, to resolve issues relating to the archive's far simpler elements. The industry intuitively senses this, and this is why it has stayed with the Gerber format.

X2 has been designed to be easy to implement and easy to adopt, as it consists of just three new straightforward commands, and support for it is growing. Graphicode is pioneering the X2 wave with GC Prevue v22.3, the industry's first X2-ready viewer software, which is now available for download. Altium too has been quick to recognise the value of X2 and will support it in the upcoming version of Altium Designer. I was recently informed that DipTrace and Kicad will also output X2 in the course of 2014, and LPKF will support it from Q1 2015. Eurocircuits and AT&S offered to beta test it, and it will be in real production by the end of 2014—less than 12 months after its introduction. This demonstrates the benefits of smart improvements: fixing what is broken but leaving in place what works well, which takes into account the community's legitimate concerns about cost and risk.

This is why I advocate X2 as the smart way forward.

Karel Tavernier
Managing Director, Ucamco

Mil/Aero007 News Highlights

Mass Design Earns DLA MIL PRF 55110 Certification

Mass Design Inc. has been awarded the Defense Logistics Agency (DLA) MIL PRF 55110 Certification, establishing this U.S.-based company as a key manufacturer of rigid, flexible, and rigid/flex PCBs for the U.S. Department of Defense.

IPC Responds to DoD on Flex Hybrid & Packaging Tech

In an effort to accelerate development and adoption of cutting-edge manufacturing technologies for making new, globally competitive products with commercial and defense applications, the Department of Defense (DoD) issued a Request for Information (RFI) on future advanced manufacturing centers called Institutes for Manufacturing Innovation, or IMIs.

FTG's Aerospace Segments Show Dramatic Q2 Improvements

"FTG's momentum has continued through the first half of 2014 with strong results across the company, particularly at our two new aerospace facilities in Tianjin and Chatsworth where we continued to see progress on qualification activities, strong orders, and increased shipments," stated Brad Bourne, president and CEO.

IPC PERM Council Addresses Lead-free Concerns

The IPC Pb-free Electronics Risk Management Council is currently meeting in Toronto, to discuss lead-free conversion issues related to the safety, performance, and reliability of electronics in the aerospace, defense, medical, and other high-performance markets. The Council develops and coordinates risk management approaches for the transition to lead-free electronics.

ACI Names Circuit Solutions Mid-Atlantic Region Rep

Bryan Ricke, director of sales and business development, stated, "We are excited to partner with Circuit Solutions LLC, led by the team of John Vaughan and Jesse Vaughan, to promote our broad and unique product offering geared to the RF community. Their outstanding reputation in the electronics industry coupled with a smart, solutions-driven and vertically integrated business model is a win-win strategy for all parties."

Dragon Circuits Achieves MIL-P-50884E Recertification

The recertification will allow Dragon to continue the manufacture of PCBs with adhesive/adhesiveless base for critical military-based applications.

Multilayer Completes MIL-PRF-55110 Recertification

Multilayer Technology is pleased to announce the completion of an additional successful recertification. This current recertification is in addition to the recent Aerospace Supplier (AS9100C) re-certification.

Former Astronaut Helps Murrietta Celebrate Award

When Murrietta Circuits received their Five Star Supplier award from Raytheon in Massachusetts last June, former astronaut and now vice president of Mission Assurance, Quality, and Raytheon's Six Sigma for Integrated Defense Systems (IDS), Robert Curbeam, handed them the award.

Canadian Circuits Nets Controlled Goods Certification

Praveen Arya, president and co-owner of Canadian Circuits, Inc. announced that his company has received its Canadian Controlled Goods Certification. This, along with their ITAR Registration, makes the company a viable PCB source for all military and aerospace companies requiring these certifications.

DARPA Details Next-Gen GPS Technologies

Several new programs are exploring innovative technologies and approaches that could eventually provide reliable, highly-accurate positioning, navigation, and timing capabilities when GPS capabilities are degraded or unavailable. Penny-sized inertial sensors, pulsed lasers, and tracked lightning strikes are among the novel approaches to provide location-based insights in GPS-denied areas.

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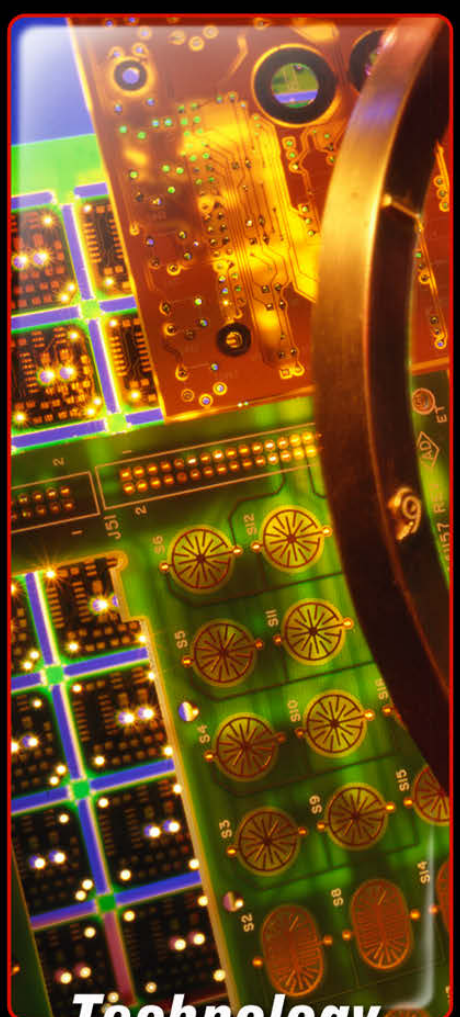

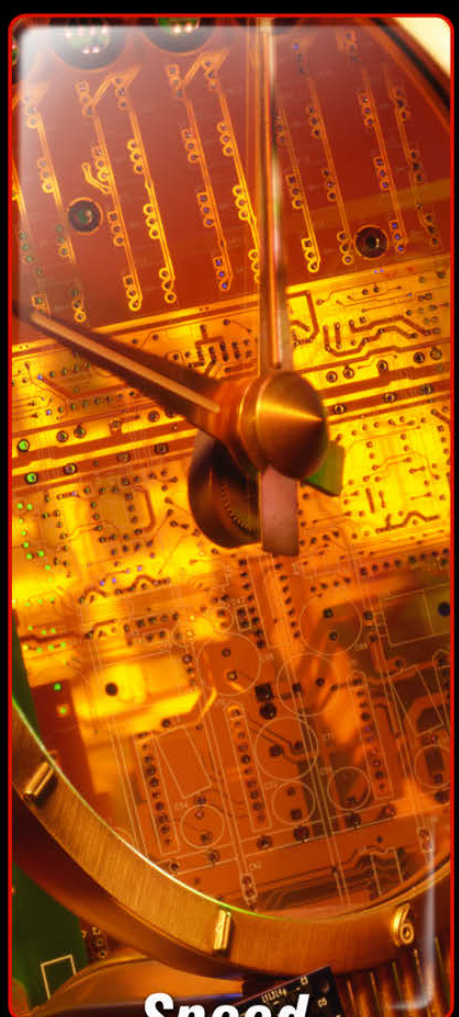

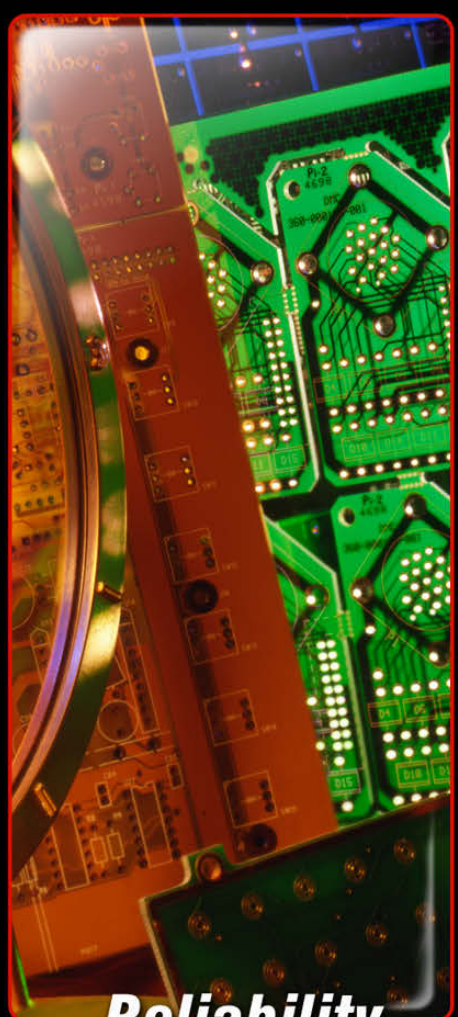

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TESTING TODD

Where do we go From Here?

by Todd Kolmodin
GARDIEN SERVICES USA

This month, Gardien's resident expert Todd Kolmodin answers questions as posed by Dan Beaulieu of DB Consulting about the future of electrical test.

Dan: Todd, do you see E-test as something that stays in the board shops or something that eventually gets so high-tech that it has to be done by experts?

Todd: That's a great question. Technology is evolving so fast now that there will be a break-point as to whether a board shop can continue to successfully test the product they are building with the equipment they have. Advances in PCB technology are quickly pulling ahead of many of the older grid test machines and forcing more of the product to flying probes, which can cause issues in capacity and velocity for testing product and force new capital investments in electrical test equipment. This can be a difficult position for a board shop as this capital expense is difficult to justify. Capital for ET machines in one sense is buying an insurance policy rather than adding any "value-add" to the PCB itself. This can be a very difficult decision for manufacturing budgets. So it is fairly safe to project that as we continue on this technology roadmap we will see more outsourcing; as for the manufacturer, it is more cost effective on the bottom line.

Dan: Do you see the equipment itself getting more sophisticated and thus very expensive?

Todd: The test equipment manufacturers will still try to make the equipment as affordable as possible, but the demands of technology are still to be addressed. In Asia, the use of quad-density grid testers and automated dedicated testers is the norm. Here in North America we have not seen too much of this technology as of yet. I have recently seen some new designs here in the U.S. that the standard double-density grid test machine cannot even test. This forces the flying probe. Soon, the need for the quad density machines will be required to effectively provide the economical test solution. This also means capital investments and yes, these machines do have higher price tags.

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Dan: What about people? Are people going to need to be better trained in the future? Will E-test get more difficult for the non-technical people to use?

Todd: Yes, we are seeing some of this today. It has been the misnomer in the past that anyone can run a test machine and in some sense that is true; but today there is much more to the equation. Many times historically there is a supervisor (expert) on the floor that sets product up and the operator then just pushes buttons. This is not efficient in today's environment. Operators need to understand prints/drawings, set up their own machine and understand what the machine is telling them. This makes the operation more efficient, reduces delays due to false calls from the testers and allows the floor supervisors to focus on higher level issues. Efficient training is absolutely critical.

Dan: I know that in some instances when independent test service companies are actually going to take over the test departments of board shops. In the spirit of full-disclosure here, I know that you're company is doing some of this already, so do you think there will be more of what I call embedded services, in the future?

Todd: I think this is inevitable. The sheer cost of capital equipment, staff and understanding specification requirements is making this function cost prohibitive within the individual manufacturing plant. All manufacturers have their FA department to review the final product for dimensional, finish, copper thickness and all other physical attributes. However, the difficulty is fully making sure all the electrical attributes are covered. We take that worry away from the manufacturer. We know the specifications; we understand the prints and customer electrical requirements.

Dan: Can you talk a little bit about new and more sophisticated types of testing will be done in the future?

Todd: There have always been more intensive tests available but in recent times we are seeing the design shops call on these tests. This includes IR (insulation resistance) testing, selective high-voltage testing, which is not to be confused with hi-pot dielectric withstanding testing. Designers are reducing the size of the PCB and this has reduced internal core thicknesses. Cores that are .002" (80 µm) and below cannot withstand the standard high-voltage hi-pot parameters that originally were called out by IPC-TM-650, so awareness and care must be taken when testing these designs. Buried passive testing is now more common and this can be both resistive and capacitive. The test department must be able to identify these characteristics and provide the optimal and correct test solution.

Dan: Let's look into that proverbial crystal ball; where do you see E-test in five or 10 years?

Todd: That is a difficult one. Technology is advancing so quickly that one could make an argument that the standard grid test machines in North America could very well be obsolete in the next five years or less. Although bed-of-nails test in North America remains stable at this point they will have to evolve in the near future. Asia has already made this leap and bed of nails machines of quad density are the norm, if not the requirement. Flying probes will cover the solution in the interim period but there will be the need for quad and ultimately, octal-density test machines. The other option is the return to dedicated fixturing and dedicated machines which use wired technology fixtures and can provide the density requirements of these new and emerging designs.

Dan: Thanks Todd, Very interesting and informative, as always. **PCB**

Todd Kolmodin is the vice president of quality for Gardien Services USA, and an expert in electrical test and reliability issues. To read past columns, or to contact Kolmodin, click here.

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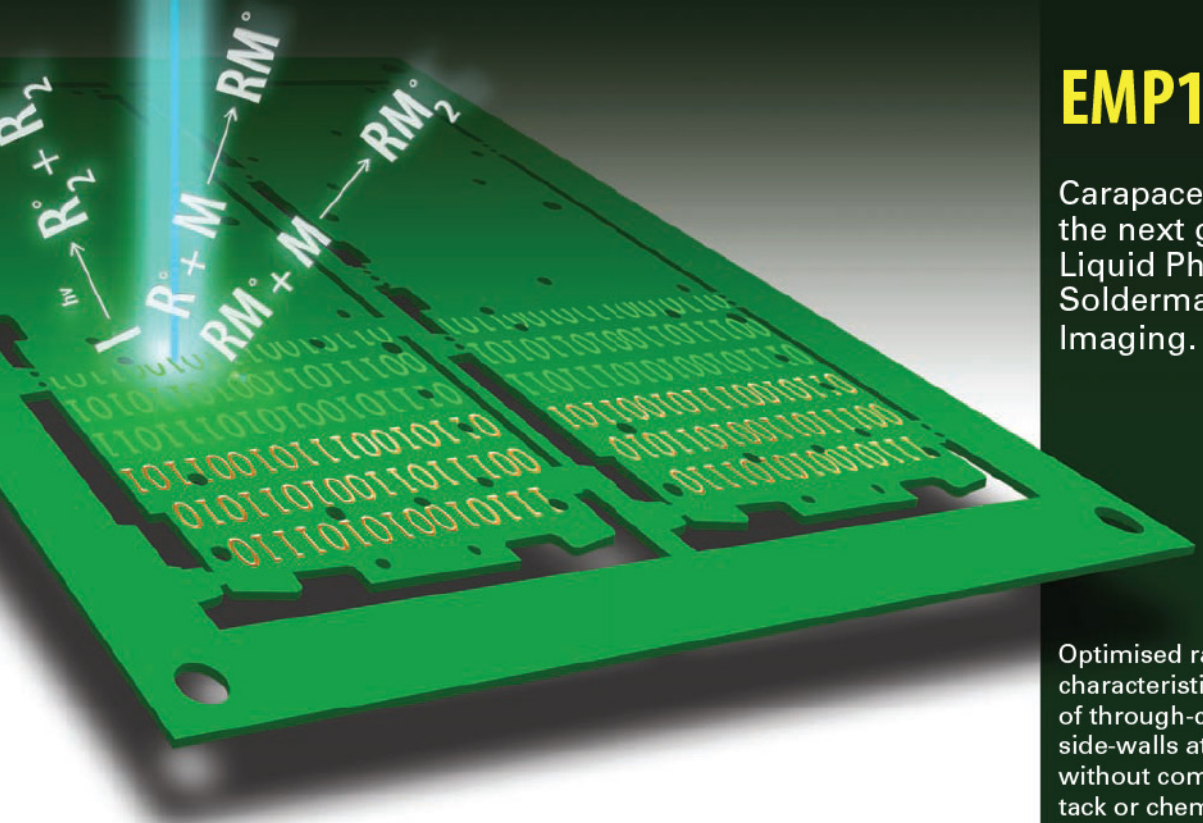

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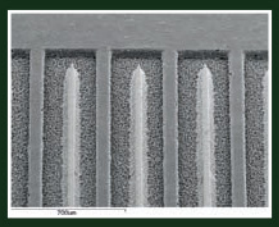

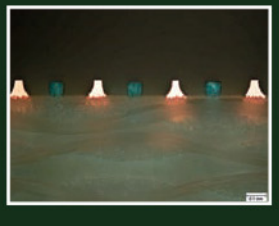

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PCB007 Market News Highlights

The Conference Board: Strong Job Growth Sustained

"The economy generated a gain of 209,000 jobs in July, very close to the average of more than 200,000 per month over the past year. This means that the trend in employment growth, which supported stellar second quarter GDP growth and strong consumer and business confidence, is holding up for now," said Gad Levanon, director, Macroeconomic and Labor Market Research.

Semiconductors in Health, Fitness to See Growth

Semiconductors providing wireless connectivity in health and fitness devices are set for solid double-digit growth in 2014 and beyond, especially as a clutch of wireless technologies make their way into a growing number of wearable devices, according to a new report from IHS Technology.

Chinese Vendors Lead Q2 Smartphone Shipments

The worldwide smartphone market grew 23.1% YoY in the second quarter of 2014 (2Q14), establishing a new single quarter record of 295.3 million shipments, according to preliminary data from the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker.

3D Printers Market in India to Witness Growth

3D printers are emerging as key growing printers in global landscape. Although the market for 3D printers is in the nascent stage in India, it holds immense growth potential in the coming years. These printers are used for designing 3D models of engineering designs, objects, prosthetics, implants, dentures, fashion accessories, art, and decoration items.

Wireless Power Transmission Market: $17B by 2020

Wireless power transmission has gradually started developing in the market and poses a huge potential in the coming future. The market is mainly driven by the consumer electronics segment for the near terms, where it is mainly used for charging the portable device which includes smart phones, tablets, and wearable electronics.

Top 20 Semiconductor Suppliers' 1H Sales Up 10%

In total, the top 20 semiconductor companies' sales increased by 10% in 1H14 as compared to 1H13, 3% higher than IC Insights' current 7% forecast for total worldwide semiconductor market growth this year.

Industrial Electronics Chip Industry Reports Positive Q1

Industrial electronics semiconductors made small, but important, gains in the first quarter this year, affirming continued strength for a sector that had been battered only two years ago. Given a heartening start, industrial electronics semiconductors could finish 2014 with $35.42 billion in annual revenue, up 9.4% from $32.39 billion last year.

U.S. Unemployment Rate Drops to 6.2% in July

Total nonfarm payroll employment increased by 209,000 in July, and the unemployment rate was little changed at 6.2%, the U.S. Bureau of Labor Statistics reported. Job gains occurred in professional and business services, manufacturing, retail trade, and construction.

Smartphone Shipments to Reach 322M in 3Q14

Smartphone shipments are expected to reach 322 million in the third quarter of 2014, up 13% on quarter, and see flat shipment growth on year in the fourth quarter, while overall shipments in 2014 will reach 1.2 billion, up 29.2% on year, according to market intelligence firm TrendForce.

Demand Uncertainty Pressures Wafer Makers

PV cell manufacturers' utilization rates continued to drop in June. "Market demand will remain weak in July before the result of the U.S.-China anti-dumping preliminary verdict is announced. Those optimistic about future demand have decided to continue with production; others have decided to focus on inventory control," said Arthur Hsu, research manager at EnergyTrend.

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Root Cause of Failures in PWB Lamination

by Michael Carano
OMG ELECTRONIC CHEMICALS

Introduction

Understanding the interactions of the materials, oxide treatment and the lamination process will help you get to the root cause failures in multilayer fabrication.

When troubleshooting multilayer defects, it is necessary to again understand the effect certain process parameters have on quality and reliability. Truly, the quality of a multilayer printed circuit board (prior to desmear/metallization) will depend on several factors that will now be presented.

Interlaminar Bond Strength

There are several quality aspects of a multilayer PCB that should be measured on a regular basis. One key determinant of the reliability of the multilayer package is the interlaminar bond strength. The interlaminar bond strength is the strength of the heat-resistant bond between the pre-preg and the copper foil. Ideally, one strives for optimum resin flow encapsulation of the pre-preg with the treated copper innerlayer. The stronger the bond between the pre-preg and treated copper, the lower the chance of delamination. Figure 1 shows an example of delamination. In general, heat excursions increased the stress within the bond and that will lead to failures. So the bond between the copper and the resin needs to be as robust as possible.

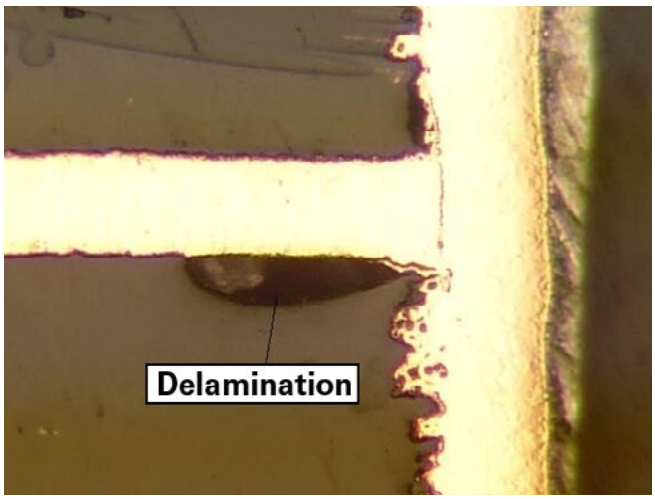

Figure 1: Delamination.

Other defects are shown in Figure 1. While additional work-up is required, there is a line of demarcation between the plated copper and the copper interconnect.

The simple definition of delamination is, "a separation between plies within a base material, between a base material and a conductive foil, or any other planar separation within a printed board." Again, we are referring to a separation. (More on blister and laminate voids in another column.) It is a huge concern that separation of the pre-preg from the copper foil is often misinterpreted for a blister. Indeed it is more serious than that. As an example, higher temperature resin systems may require more adjustments to the printed circuit processes such as: lamination cycle, baking, hole cleaning, drilling and routing. Polyimide resin and cyanate ester are the most commonly used high-temperature resin systems. These resins have T_gs in the 250°C range.

PTFE (polytetrafluoroethylene) and ceramic-filled materials are used for microwave applications and have significantly different processing conditions than the other resins. But more on this in a future column.

Factors Leading to Delamination

Delamination of the type shown in Figure 1 can be caused by several factors. Some of those factors are mechanical (press cycles, pre-preg types, multilayer stack-ups, etc.) as well as the chemical factors (oxide and oxide alternatives).

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In previous columns I presented the oxide alternative process. As you may recall, oxide alternatives function by micro-etching the copper foil and co-depositing an organic coating over the copper. It is strongly suggested that the fabricator work closely with the chemical and laminate suppliers to optimize the amount of copper etch (removal of copper). Experience has shown that some laminate material require greater amounts of copper removal in order to insure optimum bond strength.

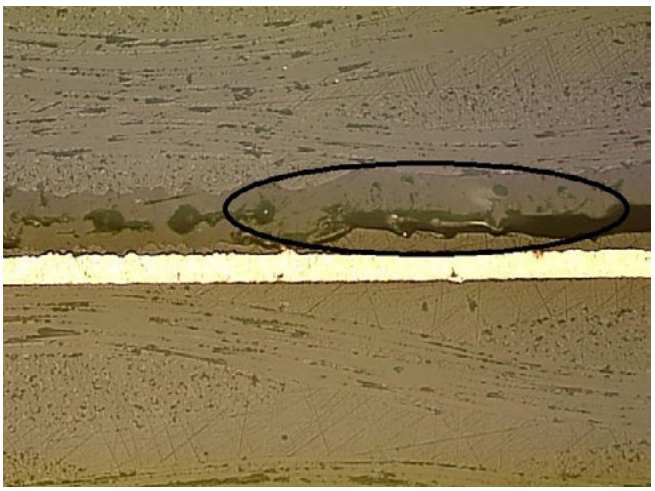


Figure 2: Delamination within the resin.

In Figure 2, the condition shown is a separation within the resin itself, not at the resin-copper foil interface. So one would troubleshoot this defect differently than if the separation was at the resin-copper foil interface.

Delamination within the resin is not an innerlayer treatment process issue. This defect is related to the quality of the resin material and the potential for moisture in the resin. Retained moisture in the laminate and resin material has a profound effect with respect to vapor pressure (Figure 3). This is further impacted by the move to lead-free assembly (impact of increased peak temperatures, 210°C > 250°C).

In order to prevent moisture from contrib-

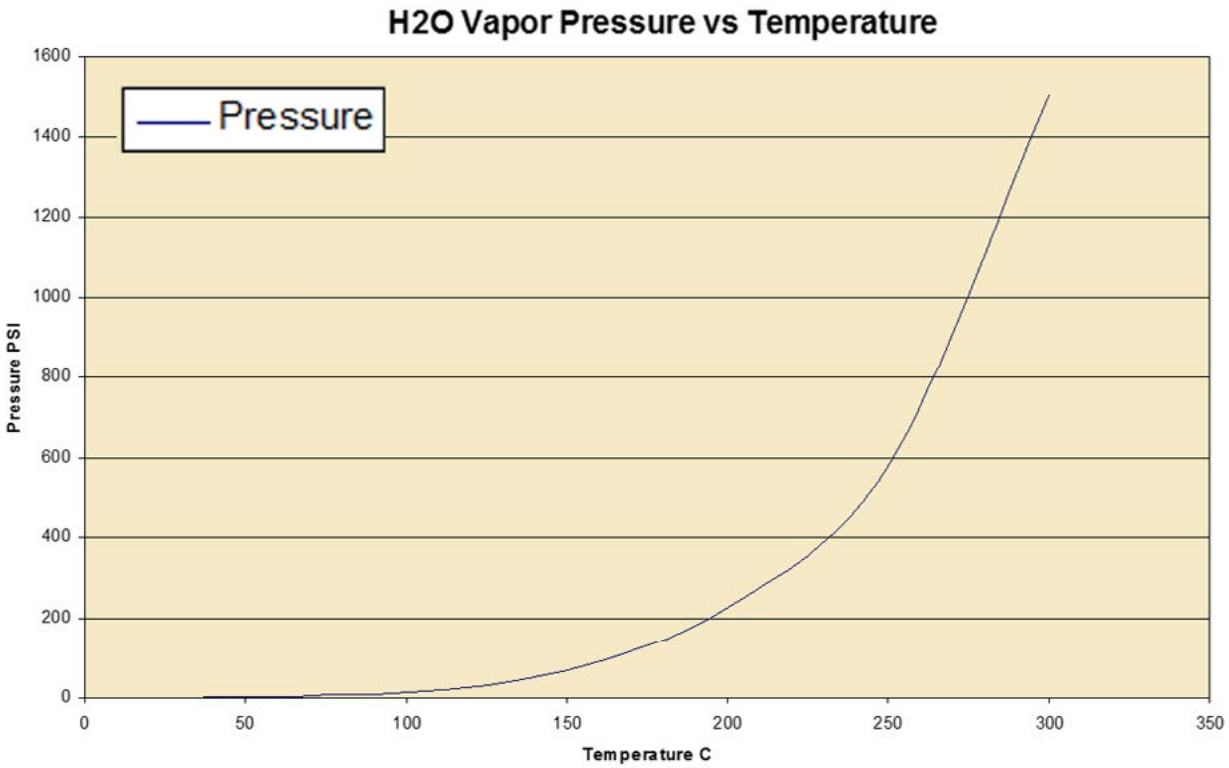


Figure 3: Effect of lead-free temperatures on retained moisture and vapor pressure.

uting to delamination, it is important that a few simple precautions be instituted:

- **Innerlayer drying**
  - Inner layers should be oven dried to remove absorbed moisture. Absorbed moisture in the inner layer can affect the curing properties of the prepreg.
- **(Innerlayer bake cycle)**
  - 225°F in vertical racks with minimum 0.5" separation for 30 minutes
  - 110°C in vertical racks with minimum 1.2" separation

Notes to consider:

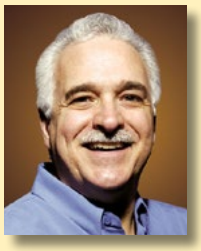
1. If inner layers are baked horizontally in stacks of 1–2" (25–50 mm) extend time to at least 90 minutes.

2. Check with oxide supplier if using DMAB oxide reducer. Excessive exposure to heat may re-oxidize the reduced treatment.

3. Drying temperatures below 100°C are not effective in removing absorbed moisture from the layer.

Summary

Again, nothing is a replacement for process control and proper shop practices. And don't underestimate the detrimental effect of moisture. Even if all of the chemical processes and lamination cycles are optimized, moisture retention in the resin and laminate package will negate all of the good that has been done. **PCB**



Michael Carano is with OMG Electronic Chemicals, a developer and provider of processes and materials for the electronics industry supply chain. To read past columns, or to contact the author, click here.

Researchers Develop Transparent Solar Concentrator

A team of researchers at Michigan State University has developed a new type of solar concentrator that when placed over a window creates solar energy while allowing people to actually see through the window. The transparent luminescent solar concentrator and can be used on buildings, cell phones and any other device that has a clear surface.

According to Richard Lunt of MSU's College of Engineering, the key word is "transparent."

"No one wants to sit behind colored glass," said Lunt, an assistant professor of chemical engineering and materials science. "It makes for a very colorful environment, like working in a disco. We take an approach where we actually make the luminescent active layer itself transparent."

The solar harvesting system uses small organic molecules developed by Lunt and his team to absorb specific non-visible wavelengths of sunlight.

"We can tune these materials to pick up just the ultraviolet and the near infrared wavelengths that then 'glow' at another wavelength in the infrared," he said.

The "glowing" infrared light is guided to the edge of the plastic where it is converted to electricity by thin strips of photovoltaic solar cells.

"Because the materials do not absorb or emit light in the visible spectrum, they look exceptionally transparent to the human eye," Lunt said.

One of the benefits of this new development is its flexibility. While the technology is at an early stage, it has the potential to be scaled to commercial or industrial applications with an affordable cost.

COLUMN

Best Practices 101, Part 2

by Steve Williams
STEVE WILLIAMS CONSULTING LLC

A few months ago, Best Practices 101, Part 1 (May, 2014) was rolled out, focusing on process analysis as the first step in this process. This issue will discuss another powerful tool at our disposal: value stream mapping.

"But we already made a process flowchart—isn't that good enough?"

In a word, no. Process flow diagrams are a great first step, but they don't tell the entire story. Value stream maps add one critical ingredient that standard process flowcharts don't have: time. Process flowcharts, whether drawn by hand or electronically, do not capture this important element. They simply present a snapshot of the sequence of steps in the process. Time is essential to understanding how one operation affects another and where your resources are being spent.

Value Stream Mapping

A value stream map (VSM) takes the basic flowchart to the next level, kind of like a process flowchart on steroids. In addition to the basic action boxes with arrows showing the flow of work, a lot of other information is added, including material and information flow, operating parameters, process lead-times, inventory, a timeline depicting value-added time relative to non-value added time, and so on. Value stream mapping is the single most effective major process analysis step to identify the value stream, and conversely, the non-value waste in your processes. The value stream is the set of all of the specific actions and activities required from the beginning of a process to the end of a process. Imagine a long and winding deep blue stream flowing through cities, counties, and states. Next, visualize all the things that the river carries within it: water, fish, minerals, plants and a thousand other elements that combine to form the stream. Processes are very much like a stream; they flow in a natural direction and carry materials and information within them from one point to another.

The activity of value stream mapping is the core fundamental method of identifying the areas of waste which can be eliminated within any process. By finding the sources of waste and quantifying them, action plans for reducing or eliminating them can be prioritized. Apart from identification, value stream mapping can also help to streamline a process for higher productivity and efficiency. Each process needs to have a beginning and end clearly identified before this can occur. This sounds simple, but since many of these discrete processes often run together, it is critical to define the boundaries of the process from a value stream standpoint. Only through a detailed process analysis can you identify the non-value added steps that have become accepted, unquestioned parts of the process that result in "the way we have always done it."

There is what I call the value stream map paradox: Value stream mapping is the most effective Lean tool for identifying high payoff opportunities, yet value stream mapping is the Lean tool most likely not to be used by companies doing "drive-by Lean."

Value Stream Mapping Steps

Value stream mapping brings together Lean concepts and techniques and helps to avoid the "cherry-picking syndrome," in which processes

iNEMI MEPTEC THE NEXT GENERATION SMTA Surface Mount Technology Association Oregon Bioscience Association

Medical Electronics Symposium 2014

September 18 & 19, 2014

MARYLHURST UNIVERSITY • PORTLAND, OR

INEMI, MEPTEC, and SMTA have joined forces to host this international conference, focusing on advances in electronic technologies and advanced manufacturing, specifically targeting medical and bioscience applications. Previously, MEPTEC's and SMTA's conferences were held in Phoenix, Arizona and Milpitas, CA, respectively, drawing technology experts, entrepreneurs and service providers that work in this niche technology space. Typical applications within this space involve implantable defibrillators, neurostimulators and drug delivery, interventional catheters, pillcams, ultrasound transducers, hearing aids, biosensors, microfluidics, wireless communications, as well as future diagnostic and treatment solutions that may use stretchable electronics, microelectromechanical systems (MEMS) or nanoelectromechanical systems (NEMS). ◆

Marylhurst University, founded in 1893, is Oregon's oldest Catholic university, and the first liberal arts college for women established in the Northwest.

Multiple Track Topics Include:

Track 1:
Components and Designs for Higher Density Functionalities

This track will focus on advances in electronics components and designs that can make current medical electronics ever more miniaturized with more functionality and at lower power.

Track 2:
Solutions for Best-in-Class Assembly and Volume Manufacturing

This track will focus on critical methods and protocols to ensure that the production of Class II and III medical electronics is conducted in the most effective, efficient and quality-controlled way with full traceability and zero defects.

Track 3:
Next Generation Microelectronics for Changing Healthcare Markets

This track will focus on advances in next generation, revolutionary microelectronics for medical devices and applications that solve technology challenges and are aligned with solutions for new healthcare models.

KEYNOTES

Digital Health and the Connected Consumer

Matthew Hudes
U.S. Managing Principal, Biotechnology
Deloitte Health Sciences

What Can Medical Devices Leverage from Consumer Electronics?

Chandra Subramaniam
Vice President CRDM Research & Development
Medtronic

Ensuring Quality Medical Devices Meet Regulatory Scrutiny in the Face of Industry Cost Pressures

Mike Tendick
Healthcare/Life Sciences Market Sector Vice President
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that have very little impact on the product or service are chosen because they will be easy to improve. Value stream mapping forms the basis of an action plan (going from current state to future state), and illustrates the linkage between information and material flows. Like most things related to Lean, or any initiative, there are some basic steps to follow when creating a value stream map. The process of value stream mapping is self-perpetuating, meaning that eventually the future state becomes the new current state and the cycle continues (Figure 1).

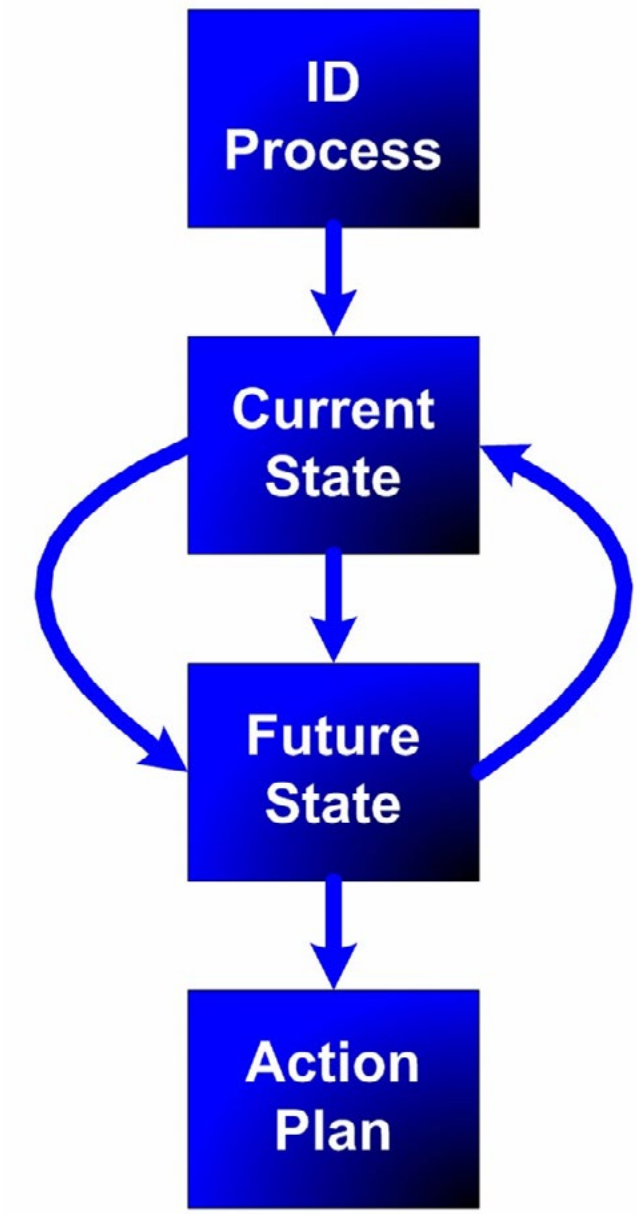

Figure 1.

Value Add vs. Non-Value Add

One of the most critical steps in the value stream creation process is recognizing non-value (waste) in the process. If we use the definition of value presented earlier, waste will be anything that the customer is not willing to pay for. Value-adding activities are tasks that that transform (add value to) the product in some way. This transformation can take the form of either hard changes to the product, or soft changes such as brand vs. private label products. Each step, of each task, of each process needs to be objectively evaluated against this criterion to successfully identify wastes that can be eliminated. The following five principles can be used to guide an organization in this evaluation:

1) Define value from the customer perspective
2) Identify the value stream for each product family
3) Make the product flow
4) Create pull to build only what is needed, when it is needed
5) Strive toward excellence

Throughout the process analysis activity, it is critical to remain focused on the right things; activities that impact improvement of the organization's products or services.

Next month, Part 3 will dive into the four critical steps of value stream mapping. **PCB**

Steve Williams is the president of Steve Williams Consulting LLC (www.stevewilliamsconsulting.com) and the former strategic sourcing manager for Plexus Corp. He is the author of the books, Quality 101 Handbook and Survival Is Not Mandatory: 10 Things Every CEO Should Know About Lean. To read past columns, or to contact Williams, click here.

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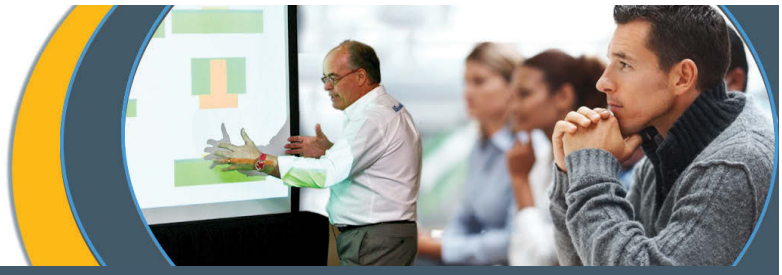

Upcoming Events

September 23–25

electronica & productronica India 2014
IPC India Conference & Workshops
Bangalore, India

September 28–October 2

IPC Fall Standards Development Committee Meetings
Co-located with SMTA International
Rosemont, IL, USA

October 14–15

IPC Europe High Reliability Forum
Düsseldorf, Germany

October 28–30

IPC TechSummit™
Reliability. Innovation. Leadership.
Sponsored by: CALCE and Lockheed Martin
Raleigh, NC, USA

November 18–20

High-Reliability Cleaning and Conformal Coating Conference
Sponsored by IPC and SMTA
Schaumburg, IL, USA

November 20

Assembly & Reliability Conference
Bangkok, Thailand

December 3–5

International Printed Circuit and APEX South China Fair
(HKPCA and IPC Show)
Shenzhen, China

February 24–26, 2015

IPC APEX EXPO®
Conference & Exhibition 2015
San Diego, CA, USA

More Information
www.ipc.org/events

Questions?
Contact IPC registration staff at registration@ipc.org or +1 847-597-2861.

TOP TEN

PCB007 News Highlights This Month

1 Viasystems' PCB Segment: Q2 Shows Improvement

"Second quarter results in our PCB segment reflect improvement in most of our end markets, both sequentially and year-over-year," noted CEO David M. Sindelar."However, we are still facing inconsistent customer project demand for our electro-mechanical solutions product offerings, which is included in our assembly segment."

2 Spirit Circuits to Acquire Teknoflex Equipment

"Sadly, trading conditions and tough competition have resulted in the demise of one the UK's longest-established flexible PCB manufacturers. Although confidence in UK manufacturing is growing, this highlights the challenges being faced by many businesses that rely on a single product offering and that do not diversify and embrace trading with offshore suppliers.

3 Exception PCB's Neil Day Awarded CID Certificate

Design Manager Neil Day has completed the IPC CID training course and attained CID certification. Training was completed at the PIEK International Education Centre in The Netherlands under the tutorage of Rob Walls and is a significant investment in the design service from Exception PCB Solutions.

4 IPC: N.A. PCB B2B Ratio Returns to Parity in June

"The PCB book-to-bill ratio has been hovering around 1.00 since February, which explains the flat year-to-date sales growth we are seeing," said Sharon Starr, IPC's director of market research. "This month's growth in orders is a positive sign, however, and if it continues we can expect to see sales improve later this year."

5 Wurth Elektronik Embraces Modern Data Formats

A new generation of PCB data formats enable a better exchange of data between CAD and CAM. The ODB++ and IPC-2581 formats include not only the graphical information for the individual board layers, but a lot of important extra information as well. All of the data required for manufacturing, testing, and assembly are contained in one file.

6 WUS Invests in Schweizer; Acquires 4.5% Stake

Following the exclusive, long-term strategic alliance for the high frequency (HF) segment, WUS Printed Circuits Co., Ltd. and Schweizer Electronic AG agreed on a capital transaction with WUS acquiring 4.5% of Schweizer's shares.

7 HEI Reports 39% Sales Drop in Q2

HEI, Inc. has announced unaudited financial results for the second quarter of 2014, which ended June 28, 2014. Sales in the second quarter of 2014 were $7,940,000, compared to $13,018,000 in the second quarter of 2013. The company generated a net loss of ($429,000) in the second quarter of 2014, compared to a net income of $678,000 in the second quarter of 2013.

8 Wurth Elektronik Combines Rigid-flex, Impedance Testing

When calculating the impedances in rigid-flex printed circuit boards, the rigid and the flexible area must be considered separately. The cause of this is the differing signal behavior due to the surrounding materials. Würth Elektronik uses a special software that calculates everything one step.

9 MFLEX Completes Restructuring, Expecting Growth in Q4

"At the mid-point of our guidance range, we expect to generate breakeven net income, excluding impairment and restructuring. With our improved cost structure in place, we should see a continued recovery in our profitability as we leverage anticipated stronger sales volume," said Reza Meshgin, CEO.

10 AT&S Posts Positive Q1 FY 2014/15 Results

The AT&S Group generated revenue of Euro 141.3 million in the first three months of the financial year, which was in line with the previous year's total (Q1 2013/14 Euro 142.5 million). Earnings before interest EBITDA amounted to Euro 29.1 million, an increase of 3.6%. Consolidated net income for the first quarter rose by 14.6%.

EVENTS

For the IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For the complete PCB007 Calendar of Events, click here.

World Engineering Expo (WEE)
September 1–3, 2014
Singapore

IMTS 2014
September 8–13, 2014
Chicago, Illinois, USA

Capital Expo & Tech Forum
September 9, 2014
Laurel, Maryland, USA

Hybrid & Electric Vehicles Forum 2014
September 17–18, 2014
Munich, Germany

Medical Electronics Symposium 2014
September 18–19, 2014
Portland, Oregon, USA

FUTURA
September 18–21, 2014
Salzburg, Austria

MEDIX Osaka
September 24–26, 2014
Osaka, Japan

SMTA International 2014
September 28–October 2, 2014
Rosemont, Illinois, USA

Standards Development Meetings
September 28–October 2, 2014
Rosemont, Illinois, USA

CEA Innovate!
September 30–October 2, 2014
Litchfield Park, Arizona, USA

World Energy Engineering Congress (WEEC)
October 1–3, 2014
Washington, DC, USA

NEPCON Vietnam 2014
October 9–11, 2014
Ho Chi Minh, Vietnam

Austin CTEA Expo & Tech Forum
October 14, 2014
Austin, Texas, USA

Long Island SMTA Expo and Technical Forum
October 15, 2014
Islandia, New York, USA

Connecticut Expo & Tech Forum
October 21, 2014
Waterbury, Connecticut, USA

Intermountain (Utah) Expo & Tech Forum

October 23, 2014
Salt Lake City, Utah, USA

Industrial Automation Conference 2014
October 23–24, 2014
London, UK

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the pcb magazine

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Coming Soon to *The PCB Magazine:*

October:
End Markets for PCBs

November:
Medical Applications for PCBs

December:
TBA