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GOOD FOR THE INDUSTRY

ENGINEERING SOLUTIONS FOR PCB MANUFACTURING

SMT® MAGAZINE

JANUARY 2015

The Rise of Structural Electronics

by Dr. Peter Harrop, page 12

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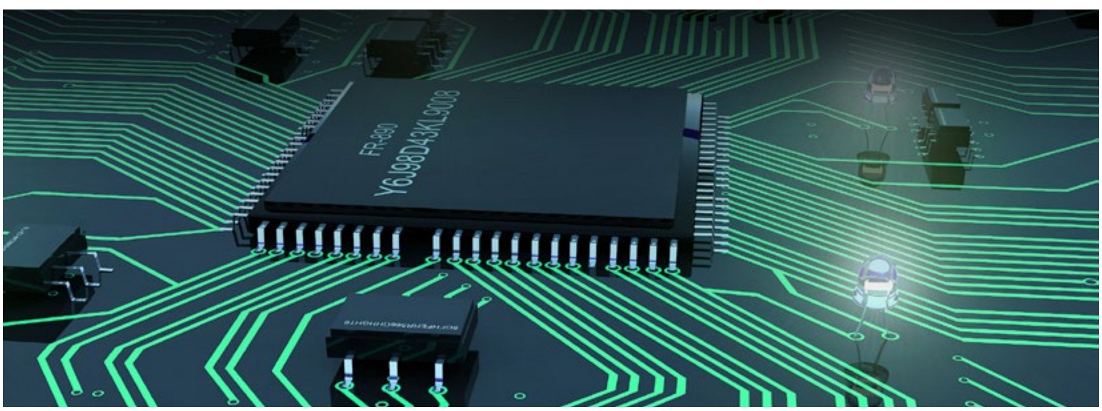
Featured Content

Structural Electronics & 3D Printing

It's a new year, and we're celebrating by focusing on a new, up-and-coming technology that could have a real effect on our industry: structural electronics. This month, you'll find feature articles by Dr. Peter Harrop of IDTechEx, and Joe Fjelstad of Verdant Electronics, as well as an article on alternative solvents by Rajat Basu and Ryan Hulse of Honeywell International. We're also introducing a new columnist, Robert Voigt of DDM Novastar, who discusses how to select the right SMT equipment.



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ENGINEERING SOLUTIONS FOR PCB MANUFACTURING

CONTENTS

THE WAY I SEE IT

The Tipping Point

by Ray Rasmussen
PUBLISHER, I-CONNECT007

A recent Qualcomm customer survey on the product development efforts around printed electronics determined the tipping for this technology is 3–5 years away. That message was part of a presentation given by a company exec during the IDTechEx printed electronics conference last November in Silicon Valley.

I pulled this definition off of Wikipedia: a tipping point is "the moment of critical mass, the threshold, the boiling point."

I have been covering the printed electronics industry for over a decade. I've read plenty of forecasts pointing to an eminent explosion in low-cost electronics all centered on PE technologies. I've also written in past columns about Gartner's Hype Cycle , which describes the path new technologies take as they move from concept to unrealistic market expectations with lots of investment (the hype), to a collapse and consolidation and then to an established market. Gartner explains it better here.

If you look at Figure 1, I'd say we're currently on the Slope of Enlightenment, headed to the Plateau of Productivity.

As I've espoused the virtues of PE technology and its potential to disrupt the PCB world as we know it, I've also been challenged by some of the industry's top professionals who believe I'm way overstating the potential impact on PCBs. Naka (Dr. Hayao Nakahara) has promised to roll a peanut with his nose from New York to San Francisco if the printed electronics industry begins to displace a majority of the PCB industry. If you believe the Qualcomm survey results, then the good news is that Naka has 3–5 years to strengthen this arms and shoulders,

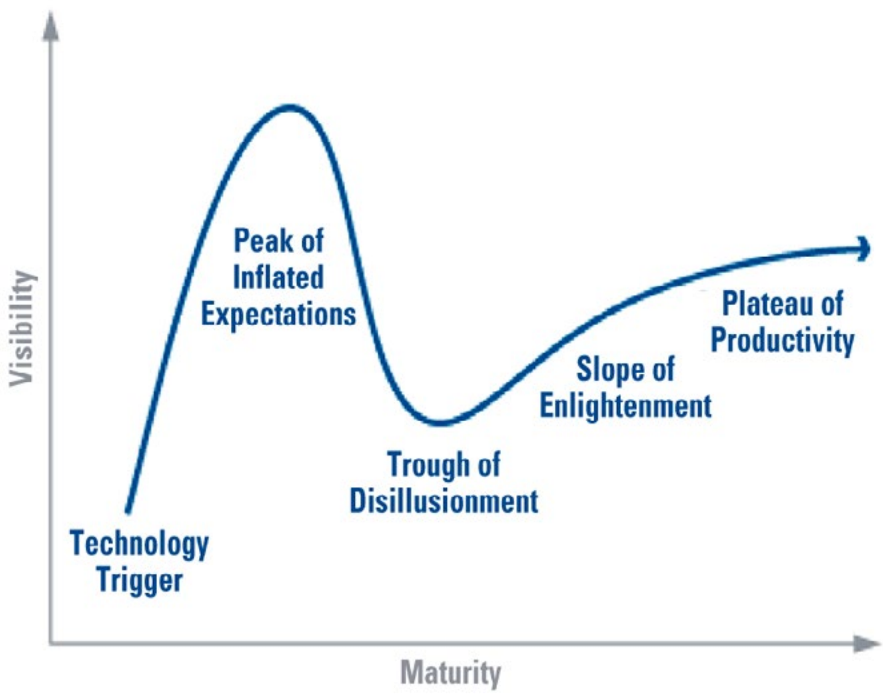


Figure 1: Gartner's Hype Cycle. (Source: Gartner Research)

which he'll need on his journey to the West Coast. Kneepads would also be recommended. But there's a lot more going on, which is why I believe that major change for our industry is on the horizon.

What many people miss is that it's not printed electronics that's driving this change. Companies aren't going to replace a PCB with PE, but they are going to redesign their products in ways which, in part, are enabled by printed electronics. There's a lot more energy going into the end products, of which PE is only a part of the story, as you'll see. PE is one of the enablers but it's not going to drive the market. It's the market that's driving printed electronics. I think that is what people don't understand. They tend to look at printed electronics as a direct replacement to the PCB, and scoff. It is the markets that printed electronics enables, which will drive its development. And each year, as PE becomes more capable, more companies will choose PE and all it enables over static PCBs. Keep reading.

These new markets will drive the PE industry forward at an ever-increasing rate. The capabilities of the technology will advance faster than that of traditional PCBs and therefore, seemingly overnight, blow by the PCB industry. PE will not likely ever be in direct competition with PCBs. Once OEMs start using PE solutions (interconnects) and structural electronics (see below) to build their products, game over.

The Drivers: the Electronification of all Things

Over the last few years, the IDTechEx show has been expanding with some complimentary offerings on topics that include: 3D printing; energy harvesting and storage; internet of things (IoT); wearable technology; and super capacitors. To get a sense of these emerging technologies you should make the trek to one of these conferences. Spend a couple days listening to the speakers and walking the show floor. There's a lot going on. If the potential of PE wasn't real, this show would have died out years ago. Instead, hundreds of Silicon Valley engineers attend the courses, talk to exhibitors, and network with their peers. And globally, there are dozens of shows and conferences from major industry groups addressing these topics. What's happening is definitely for real.

By looking at these additional offerings from the conference, you can start to see where printed electronics is headed. There's a monster industry developing. And, what has started out slow, focused on low-cost products, will quickly jump into all markets, making just about everything you can think of smarter. And looking at PCBs, the PE technologies for making circuits are getting really good. Very, very fine lines are producible in high volume using many different techniques. The paper companies talk about PE using thermal paper, roll to roll. Printing presses are now producing multilayer circuits (as predicted) on the fly, printing conductors and insulators back to back. Inkjet printers are getting really good along with the inks and substrates. But again, you can't just look at the PE capabilities and match them up to a PCB. I believe there will only be a very short span of time when they actually intersect. We're seeing some of that, now.

Structural Electronics

As I mentioned earlier, there is something new, currently being called structural electronics. It has been talked about in theory for years and in the past, been done in the form of molded circuits, but this specialty market segment is poised for growth, soon. The marriage of 3D (also not new, but now taking off) and printed electronics can provide distinct advantages to those OEMs willing to take the plunge. It seems inevitable that all products will incorporate structural electronics at some point. That's the way it's all headed. You won't build a product by integrating the electronics into it. We may see structural electronics added to the IDtechEx conference next year, as a standalone, as more companies seek to meld electronics into everything. This is bigger than most of us can get our minds around.

Here's an excerpt from a news item we published back in November:

Structural electronics involves electronic and/or electrical components and circuits that act as load-bearing, protective structures, replacing dumb structures such as vehicle bodies, or conformally placed upon them. It is of huge interest to the aerospace industry which is usually the first adopter, the automotive and civil engineering industries, both with compelling needs, but its reach is much broader even than this. Electric cars badly need longer range and more space for the money, and in civil engineering, corrosion of reinforced concrete structures and tighter requirements for all structures, including early warning of problems, are among the market drivers for structural electronics.

You can read more about this rapidly evolving market here.

If you do some digging you'll find much more on this topic. The Internet of Things, which promises to connect everything with very inexpensive (or, not so inexpensive) electronics built into and onto just about everything you can imagine, is changing the game. A crude example is the integration of sensors into the pillars, surfaces and joints of a bridge. Before the bridge even shows a sign of a problem, the sensors have detected an anomaly and that information is transmitted to the builder, the architect, the engineers, and more. In this scenario, the surface sensors could weigh trucks as they pass and give a real-time traffic count and even collect solar energy, the joints would track ground tremors, etc. The sky's the limit on what's possible. Now, think of everything out there where failure is not an option and you can see what's driving this. The military/aerospace and medical, along with transportation companies are driving this hard. They have the most to gain, initially.

IDTechEx said this recently:

Nonetheless, the big picture is structural electronics taking over from a century of joining components together and putting them in a box. Now is the century of electronic and electrical structures with a very different value chain.

Read more here.

When we talk about electronic products today, they are usually in a class by themselves, as add-ons bringing intelligence to some piece of equipment, as mentioned above. Soon, everything will be an electronic product to some degree, which will have a structural component, or vise versa: roads, bridges, walls, floors, ceilings, tires, pots for plants (as I look around my office), fireplaces, lamps, desks, water and sewer pipes—you name it. That's where this is heading.

I hope you enjoy this month's topic. **SMT**

Ray Rasmussen is the publisher and chief editor for I-Connect007 publications. He has worked in the industry since 1978 and is the former publisher and chief editor of CircuiTree Magazine. To read past columns, or to contact Rasmussen, click here.

The Rise of Structural Electronics

by Dr. Peter Harrop
IDTECHEX

Structural electronics (SE) is one of the most important technological developments of this century. It forms a key part of the dream, first formulated thirty years ago, of computing disappearing into the fabric of society. It also addresses, in a particularly elegant manner, the dream of Edison in 1880 that electricity should be made where it is needed. SE is often biomimetic: It usefully imitates nature in ways not previously feasible. An example of this is providing an aircraft or a car something resembling a human nervous system. The new IDTechEx report, Structural Electronics 2015–2025, sees this market climbing strongly to nearly $90 billion in 2025, with the aerospace and automotive sectors particularly important adopters.

Structural electronics effectively takes no space because it is integrated into something already there, achieving this by adding little if any weight increase to the integrated structure. However, the design rules change as we move from component selection and circuit design to functional design.

Structural electronics involves electronic and/or electrical components and circuits that act as load-bearing, protective structures, replacing dumb structures such as vehicle bodies or conformally placed upon them. The common factor is that both load-bearing and smart skin formats occupy only unwanted space. The electronics and electrics effectively have no vol-

Aerospace	Automotive	Civil Engineering
Lighter weight structures to improve performance and reduce pollution. Longer range electric aircraft of longer life will be achieved by laminar structural batteries that may not need water cooling, conformal photovoltaics, etc. New functions needed.	Move to hybrid and pure electric vehicles such as e-cars calls for major weight and volume reduction to reduce cost and increase range. Also needed is replacement of batteries because they need very expensive replacement well within the life of the vehicle.	Severe, unpredicted corrosion of reinforced steel concrete in bridges, tunnels and buildings calls for strengthening retrofit with embedded sensors. In Japan, carbon fiber is spun around the support structure and embedded in polymer with sensors as a smart skin. Need to generate electricity locally from floor movement, sun on the roof, walls, etc.

Table 1: The sectors most likely to benefit from SE. (All tables and graphics courtesy of IDTechEx.)

ume. Initially, SE is seen as vital in tackling certain global problems in certain applicational sectors. These are shown in Table 1.

Primary benefits

The benefits and challenges of structural electronics are compared in Table 2.

Maturity by Applicational Sector

Most of the pioneering and early application of structural electronics lies in aerospace with other applications being at an earlier stage or, as yet, less sophisticated as shown in Figure 1. The typical time lag after adoption in aerospace and military applications is given, but there are many exceptions.

Objectives and Benefits

The objectives and benefits of structural electronics are broader in certain applications as shown in Table 3.

Figure 1: Maturity and sophistication of applications of structural electronics by sector, showing strong adoption in yellow, intermediate in green and later adoption in magenta.

Benefits	Challenges
Saves space.	For most of the benefits, SE needs to be designed into a structure such as a bus or a train when it is at the early conceptual stage. Often impracticable or too expensive as retrofit.
Saves weight. Fiat believes that cars, with about half their weight in bodywork and half in circuits and comfort facilities, could save about 20% in weight by merging some of these into structural electronics. For a pure electric car that means a precious increase in range of over 20%, but it does not stop there. New circuits such as telematics and vibration harvesting can also be designed into the structure, saving even more weight.	Thin film, printed and other flexible forms of electronics are less efficient than bulk initially making it impracticable or too expensive to add more to compensate, for example with photovoltaics, supercapacitors or lithium-ion batteries.
Pervasive wide area electronics such as photovoltaics over the whole airframe of an aircraft and sensing in places previously inaccessible.	Photovoltaics is often much less efficient.
Systemic change such as providing a bridge or an aircraft with a nervous system mimicking that in the human body.	Expense.
Makes large components vanish. For example, supporting huge areas of photovoltaics has previously been expensive and troublesome. The weakness of supercapacitors is that they have considerable weight and size per unit of energy stored is overcome. This means that they can replace more batteries because their other properties are greatly superior such as life, reliability, fast charge/discharge, ability to be fully discharged for safe transit and in an accident. Harvesting small vibration over a large area becomes feasible.	Supercapacitors are much less efficient in the new format.
Replaces expensive, delicate, bulky and unreliable components. A typical car employs around 50 tactile switches and four rotary switches, both being relatively unreliable. For example, the overhead console of a car with switches for lighting, etc., can be made much thinner, shaped and solid state with a saving of up to 40% in cost, weight and space, and potentially an increase in reliability, including better waterproofing.	Alternatives for conventional switches are not usually haptic (you feel what you do) and therefore can be false (e.g., conductive decorative features on the plastic layers can interfere electrically and switches can be activated accidentally from too far away in some early designs). Devices such as batteries that swell and shrink in use are difficult to contain in a structural material and when, after their relatively short life, they fail and need replacement, the whole structure will need to be replaced, probably expensively and costing much time and effort.
New functionality.	Moving parts such as electric traction motors, internal combustion engines, fuel cells and pumped refrigeration are usually impossible in SE.
Potentially it can reduce up-front cost.	First execution may be expensive.

Table 2: The benefits and challenges of structural electronics.

Location	New function, e.g., nervous system	Increased reliability and life of function	Save space	Save weight
Aerospace land vehicles	✔	✔	✔	✔
Buildings, boats, wind turbines	✔	✔	✔	
Bridges, dams, tunnels, ships, rolling stock and rail infrastructure	✔	✔		

Table 3: Benefits of structural electronics in different structures, materials and processes.

Fiber-reinforced plastic (FRP) is a commonly used host structure in SE, with carbon fiber increasingly used rather than glass fiber. For example, it is spun around the supports of failing Japanese bridges then set with sensors in resin as a form of "smart skin," so to speak. Among the favourite processes will be printed electronics and lamination of thin flexible layers, often using in-mold electronics which typically employs thermoplastics. Smart materials are increasingly used, with piezoelectrics being popular among these.

<table>
<tr><th>Location</th><th colspan="2">Host</th><th>Electronics</th><th>Mainly new or retrofit</th></tr>
<tr><td>Land vehicles, aircraft, aerospace</td><td rowspan="3">Can include carbon fiber composite and polymer load-bearing parts replacing dumb parts and can include smart skin—protective and functional in one structure</td><td></td><td rowspan="3">Usually sensors, often actuators and other things as well. Conformal photovoltaics. Sensors increasingly do other tasks such as lighting conductor in non-conductive host.</td><td>New</td></tr>
<tr><td>Buildings, boats</td><td rowspan="2">Concrete for buildings, bridges, dams, tunnels</td><td>New and retrofit</td></tr>
<tr><td>Bridges, dams, tunnels, ships, rolling stock and rail infrastructure</td><td>Retrofit</td></tr>
<tr><td>White goods</td><td>Polymer</td><td></td><td>Capacitive actuators and sensors</td><td>New</td></tr>
</table>

Table 4: Certain patterns emerge between applications.

Evolution

We can understand the evolution of structural electronics in recent years and where it is going as shown in Figure 2.

Smart Skin

Smart skin is a much more powerful concept than at first seems to be the case, and in

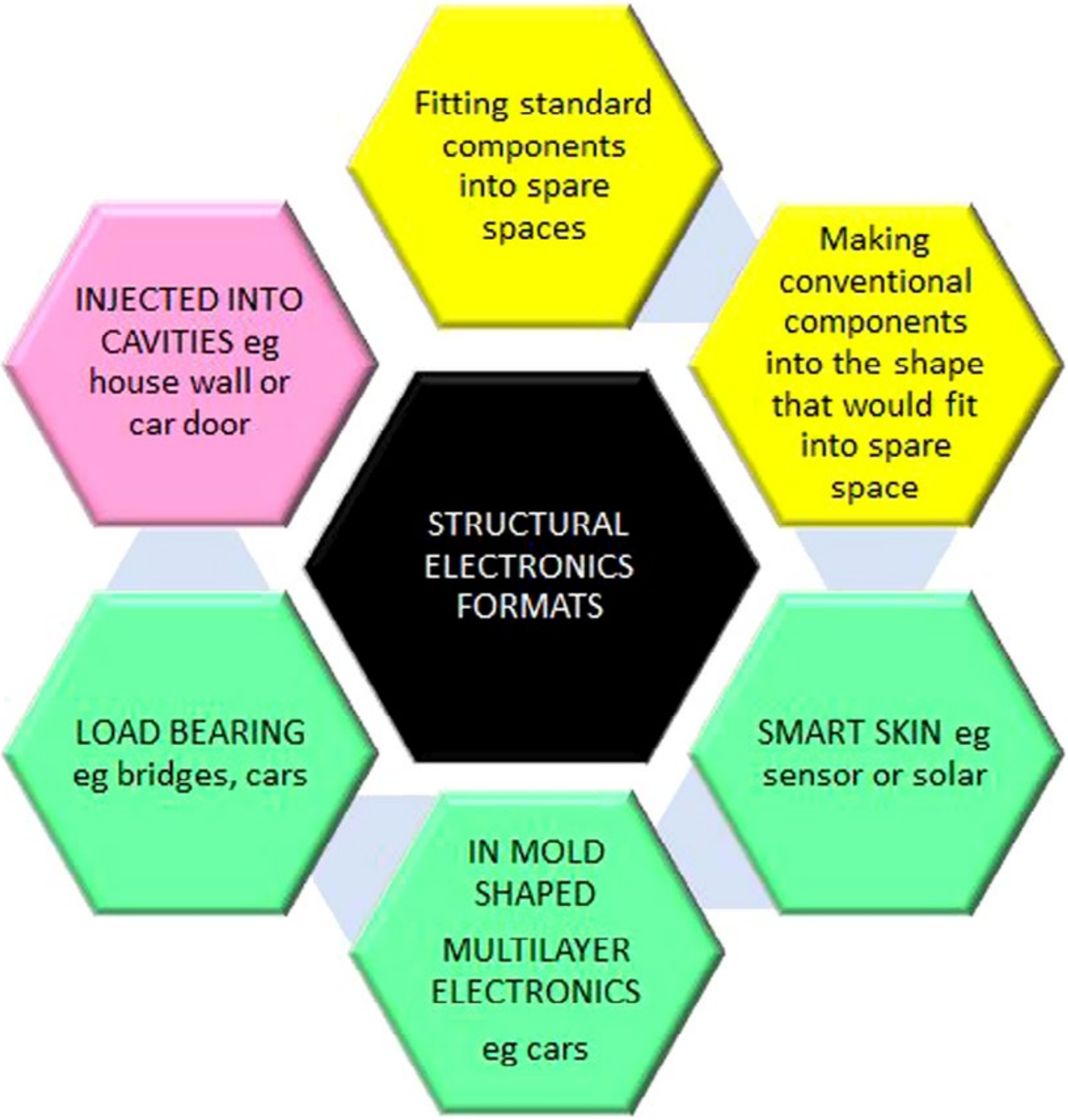


Figure 2: Precursors of structural electronics in yellow, transitioning to established technology in green, and speculative dreams in magenta.

this report we show how it will even extend to sheathing of conductor wires and cables. Further, electronic smart skin is becoming multilayer and multifunctional. Transparency in the outer layers can permit inner layers to function as photovoltaics, light sensors, etc.

The smart skin cannot simply be flexible in one direction from a roll-to-roll production line if it is to be widely applied across a vehicle. The IDTechEx report, "Stretchable Electronics and Electrics 2015–2025: Technologies, Markets, Forecasts," analyses and forecasts progress in this field. However, for now, stretchable electronics is feasible only in smaller formats such as skin patches.

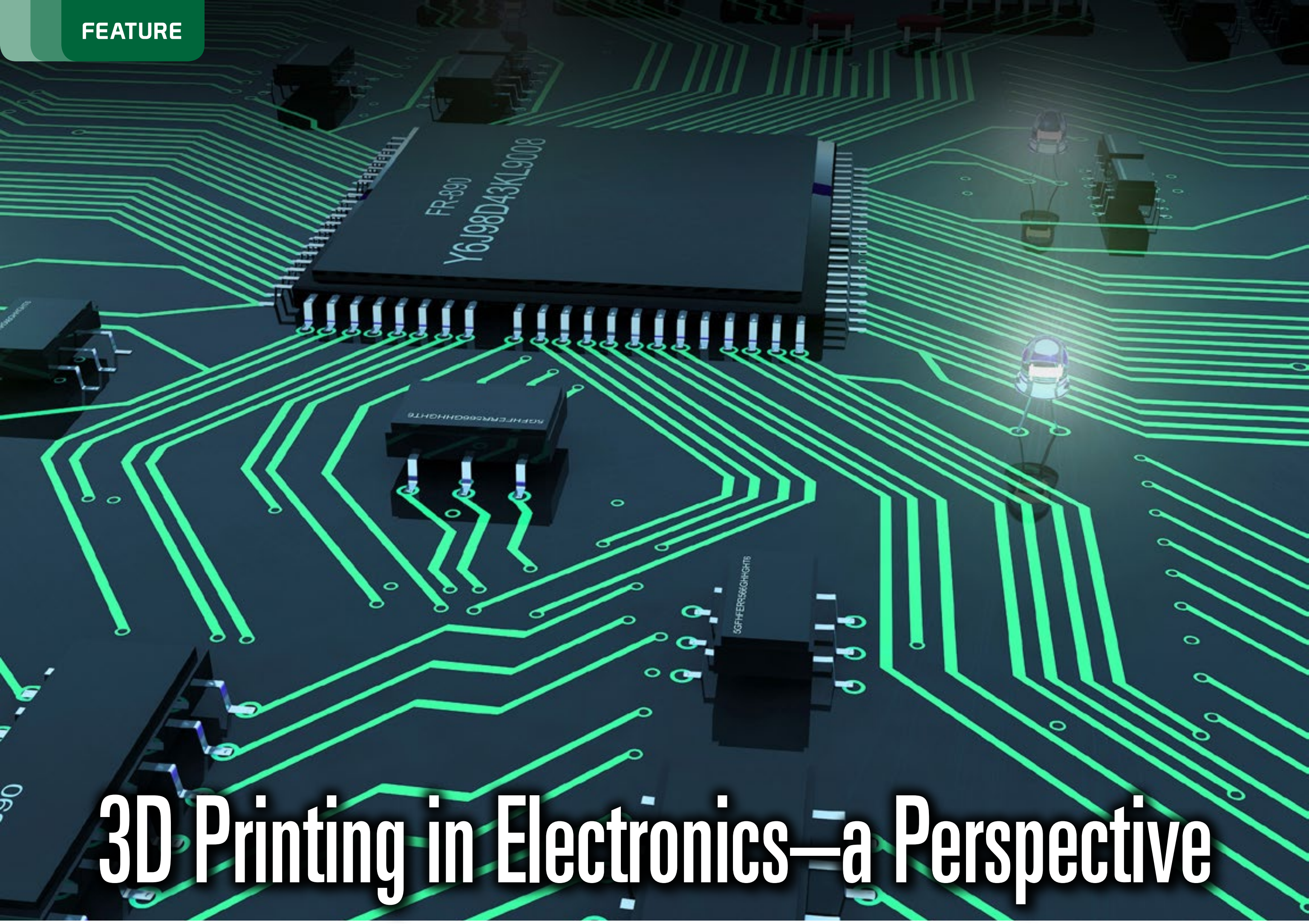
In short, structural energy storage and energy harvesting are being pursued by building up a load-bearing structure or applying a smart skin, but is there another way? Why not spray it on? It does not matter if the photovoltaics or supercapacitor storage has poor performance by unit of area when applied in this way because huge area is usually available. Indeed, spray-on

cells hold considerable promise for reducing the manufacturing costs of solar power.

Scientists at the University of Toronto have recently announced a new method for spraying quantum dot solar cells onto flexible surfaces. They dream of coating anything from bicycle helmets to outdoor furniture one day. Quantum dots provide versatile photovoltaic material because they have a band gap that can be tuned by altering the size of their nanoparticles, soaking up different parts of the solar spectrum. The team recorded solar efficiency of eight percent, way better than earlier sprayed photovoltaics and similar to flexible organic photovoltaic-coated (OPV) film though much less than that of commercially available glass panels. According to the researchers, covering the roof of a car would generate 300W, comparing well with today's rigid patch on a car which offers 100W peak at best.

A two-day conference, Electric Vehicles: Everything is Changing, will address many of these issues in Berlin, Germany, April 28–29, 2015. It will concentrate on future components and smart materials for electric vehicles land, water and air. The conference will form a part of the major IDTechEx event covering relevant technologies such as structural electronics, printed electronics, 3D printing, in-mold electronics, wireless sensors, Internet of Things, and energy harvesting including photovoltaics deposited in new ways. The event will offer nine parallel conferences and an exhibition of over 150 stands plus many optional masterclasses on the days before and after. Among them will be a class on the electric vehicle markets and technology and others on the specifics of electric vehicles. **SMT**

Dr. Peter Harrop is chairman of IDTechEx Ltd. To contact him, click here.

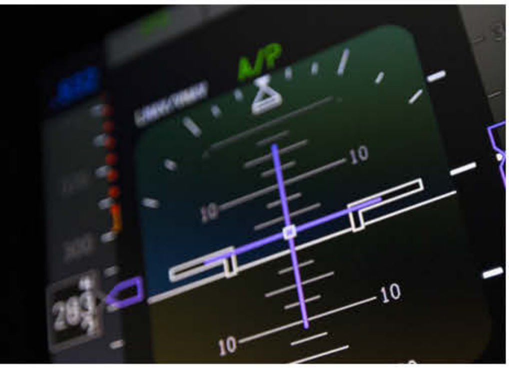


3D Printing in Electronics—a Perspective

by Joe Fjelstad
VERDANT ELECTRONICS

"A cynic," according to Irish playwright and humorist Oscar Wilde, "is a man who knows the price of everything and the value of nothing." Anyone who has spent any time dealing with purchasing agents could easily find a way to apply that same definition to those poor souls whose job it is to get the best price (i.e., lowest cost) on everything they purchase for their companies. The problem is that they are not required to make value judgments about the things they purchase; they just need to get those items in the door within budget and on time. This is a tragedy of sorts because if they possessed a better understanding of the nature of the products they purchase, those individuals could well be making informed decisions that could more positively impact the bottom line of their companies. Knowing the value of a product or technology is a key element in making the right decision. Appreciating the value proposition of an element of business is ever more important as the rate of change that surrounds an industry continues to accelerate. This brings us to one of the current buzz subjects in our industry: 3D printing. Understanding what 3D printing is and what its value is to a company and that company's ability to hold or improve its place in the industry is vital.

First, a question to ponder: What is the most valuable factor in business and life? The customary response is often money or capital. Money is, after all, the lifeblood of industry and key to a life free from want. Without capital investment there is no business and without money on an individual scale one might find themselves out on the streets. On the bright side, capital/money can often be raised if there is a believable opportunity to recoup its investment and ideally some amount of profit and an investor who shares that belief. There are also social safety nets which exist (even if imperfect) to help out the unfortunate individual lacking funds.

No, money is not the most important factor in business and life; that spot is reserved for time and its close kin, timing. Time and timing are arguably the most important factors. Businesses and individuals alike enter the world with a finite life ahead of them. Time may be infinite but we are not and neither are businesses. The list of highly successful companies that have come and gone is very long. Knowing this, the value of time should be patently obvious. This is where 3D printing appears to have a vital role to play in the world of businesses which manufacture hard products. 3D printing allows the manufacturer to make mistakes at a prodigious rate enabling much faster cycles of learning than have ever been available to the willing student.

Circling back to the answer to the question posed earlier, the astute reader has likely already picked up on the nexus between time and money. "Time is money," as the old adage goes. It is especially true in the arena of product markets and product introductions. Simple math is all that is required to understand the potential impact. For example, if a prospective market size is projected to be $100 million a year and a technology is available that allows one to enter that market six months sooner than the competition, the reward is one half of the total available market or $50 million provided the product delivered meets with all customer demands and expectations. With electronic products with ever decreasing product cycles this is especially true.

Those who have studied 3D printing to any depth know that the concept is not all that new, having been introduced in the mid-1980s. The technique was originally called stereolithography and the machines SLAs (stereolithographic apparatus). The original SLA machines were comprised of a vertically movable platform residing in a vat of liquid polymer resin and a laser beam capable of hardening the surface of resin when exposed to the laser's energy. Like today's variants of the technology, the object was produced a slice at a time. With each pass, the platform was lowered slightly and additional slices produced. When completed, the platform was raised and the completed object removed after the resin had drained away. Today, 3D machines use a variety of different methods and materials including paper, plastics, metals and ceramics often in combinations and in a wide range of colors. The mix of plastic and/or ceramic and metal is of the highest interest to those in the electronics industry. One company, Eo-Plex, markets QFN packages which are entirely additively processed using 3D methods.

> **"Today, 3D machines use a variety of different methods and materials including paper, plastics, metals and ceramics often in combinations and in a wide range of colors. The mix of plastic and/or ceramic and metal is of the highest interest to those in the electronics industry."**

It is unclear if 3D printing will ever be suitable for the highest volume production, but its versatility is perhaps one of its greatest attributes. Being able to produce prototype products in a matter of hours directly from CAD files is immeasurably valuable because of the immeasurable value of time.

Let's examine the potential application of 3D prototyping methods to the production of a manufacturing system capable of fabricating an electronic assembly using nothing but presently available equipment, materials and processes and wherein the use of solder is not required.

1. Place the electronic components on a tacky carrier to affix them temporarily according to design plan.
2. Scan the assembly with a laser to define the outline of the components (including batteries if desired).
3. Print in 3D the results of the scan, creating a base sheet with cavities which match the outlines and dimensions of every component and place the components into them.

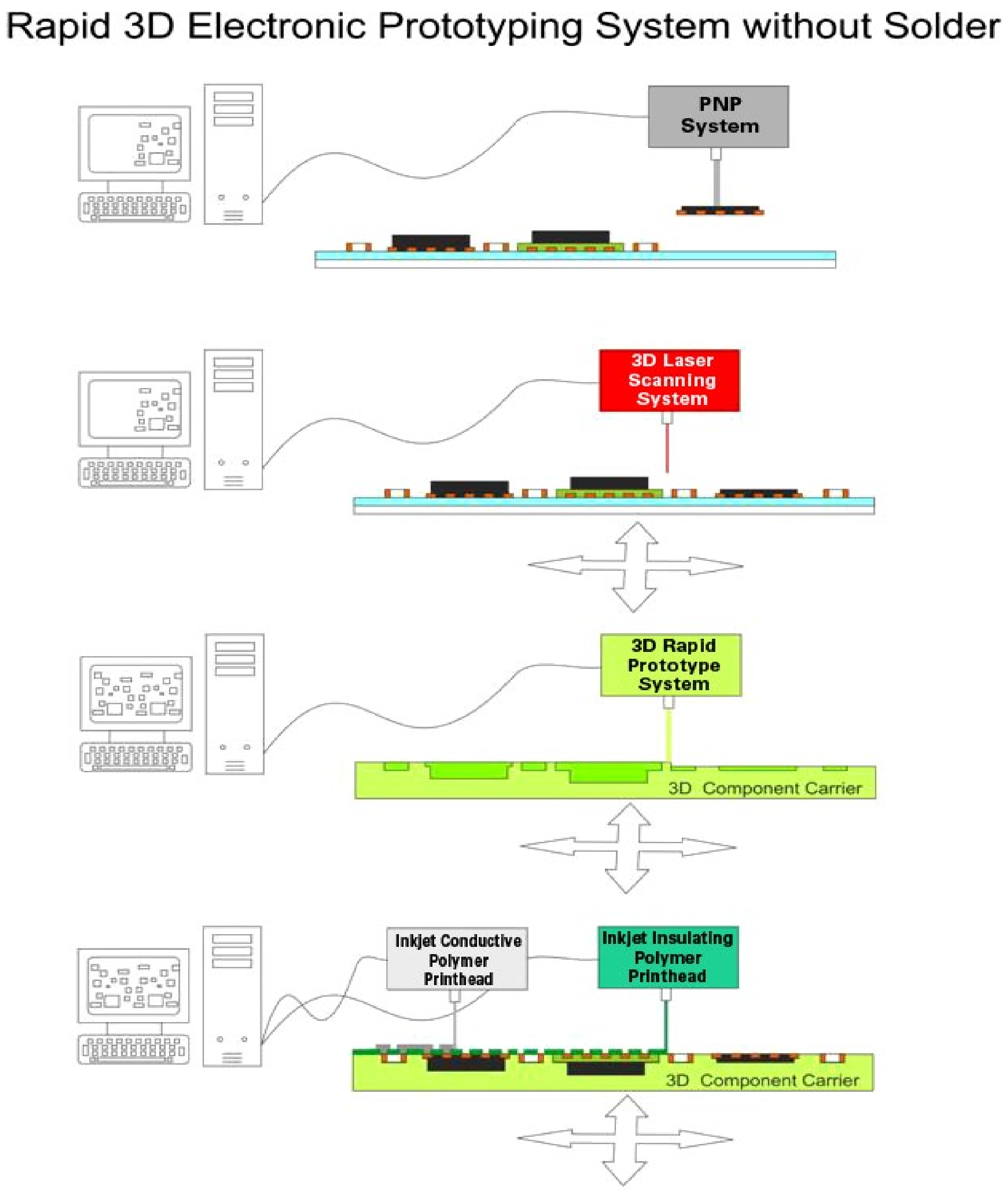


Figure 1: Conceptual system for producing electronic assemblies. The complete manufacturing system could occupy a relatively small footprint and be capable of producing assemblies in as little as a couple of hours.

4. Print a layer of insulation over the top of the exposed components leaving open the desired terminations, followed by printing of conductor traces. (Resistor materials could be printed into terminations also if desired to reduce component count.)

These last two steps, insulators and conductor layer printing, are repeated as needed until

all required connections are completed. While there are nuance elements missing from this description, the practical results are fundamentally a working electronic assembly built in a matter of a couple of hours rather than days, weeks or months.

In summary, 3D printing is coming on strong as a method for making rapid prototypes for many purposes and markets. Electronic products are unlikely to be left out of consideration when the power of time conservation gets the attention it so richly deserves. **SMT**

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.*

2D Materials Stacked for Cheaper Semiconductor Devices

A team of researchers led by North Carolina State University has found that stacking materials that are only one atom thick can create semiconductor junctions that transfer charge efficiently, regardless of whether the crystalline structure of the materials is mismatched—lowering the manufacturing cost for a wide variety of semiconductor devices such as solar cells, lasers, and LEDs.

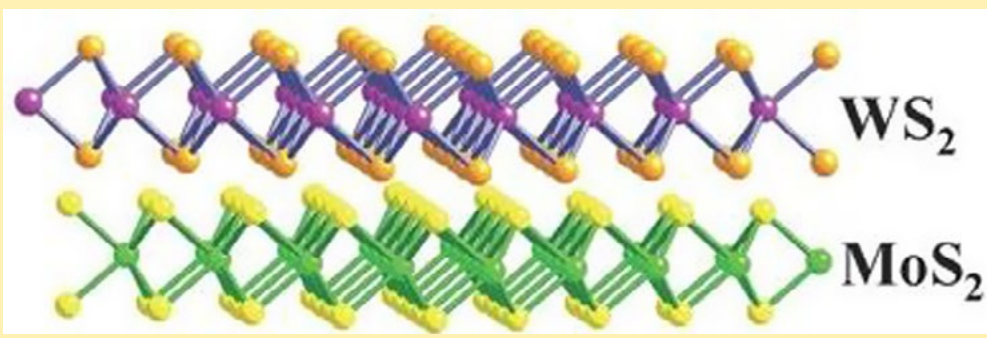
"This work demonstrates that by stacking multiple 2D materials in random ways, we can create semiconductor junctions that are as functional as those with perfect alignment," says Dr. Linyou Cao, senior author of a paper on the work and an assistant professor of materials science and engineering at NC State.

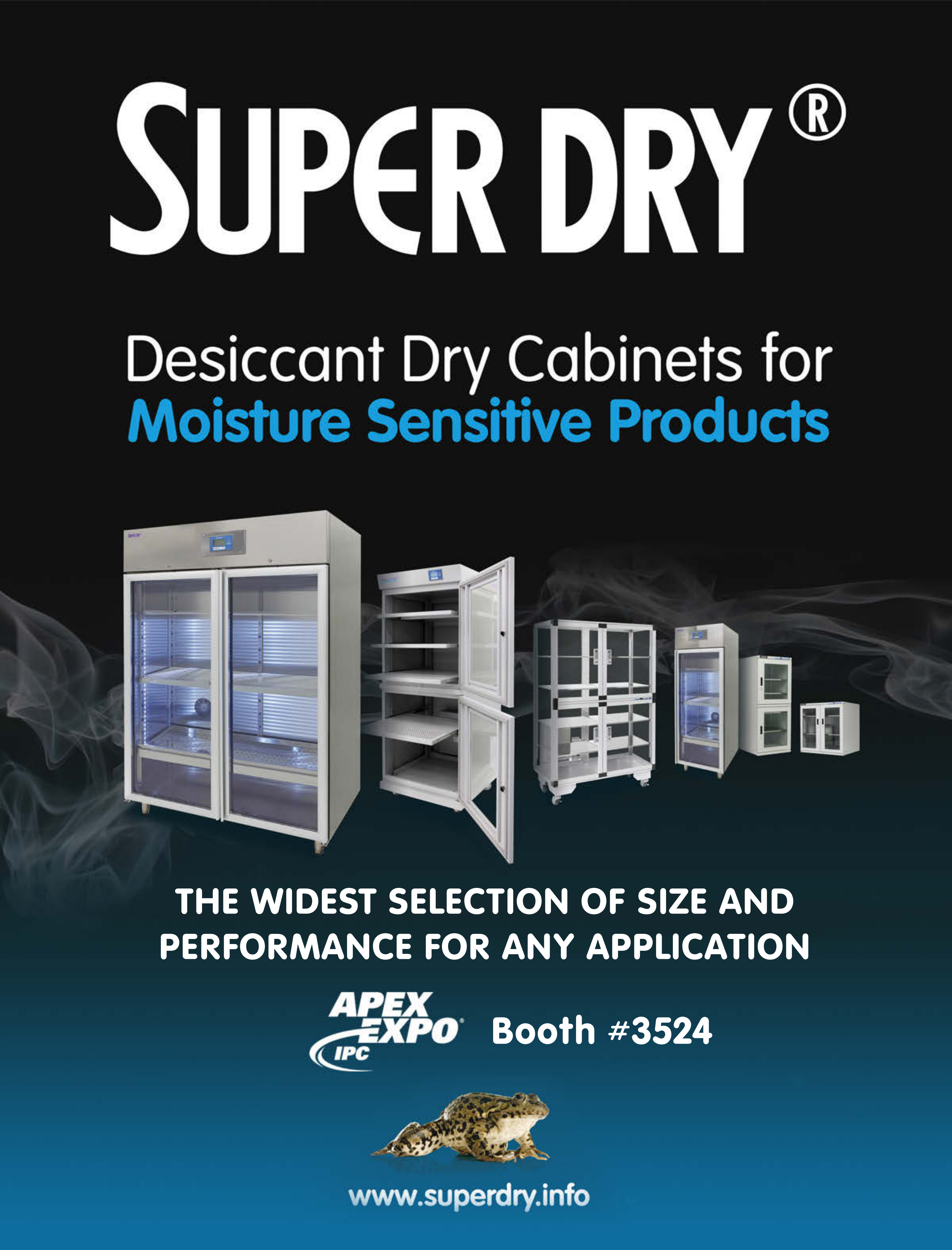
"This could make the manufacture of semiconductor devices an order of magnitude less expensive."

For most semiconductor electronic or photonic devices to work, they need to have a junction, which is where two semiconductor materials are bound together. For example, in photonic devices like solar cells, lasers and LEDs, the junction is where photons are converted into electrons, or vice versa.

All semiconductor junctions rely on efficient charge transfer between materials, to ensure that current flows smoothly and that a minimum of energy is lost during the transfer. To do that in conventional semiconductor junctions, the crystalline structures of both materials need to match. However, that limits the materials that can be used, because you need to make sure the crystalline structures are compatible. And that limited number of material matches restricts the complexity and range of possible functions for semiconductor junctions.

"But we found that the crystalline structure doesn't matter if you use atomically thin, 2D materials," Cao says. "We used molybdenum sulfide and tungsten sulfide for this experiment, but this is a fundamental discovery that we think applies to any 2D semiconductor material."

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Electronics Industry News
Market Highlights

IoT, M2M Market Worth $947B by 2019

The Internet of Things market & M2M communication to grow from $255.87 billion in 2014 to $947.29 billion in 2019, at an estimated CAGR of 29.9%.

Cost Index Shows Weakness in Commodity Prices

Construction costs rose for the 34th consecutive month in November, according to IHS and the Procurement Executives Group (PEG). The headline current IHS PEG Engineering and Construction Cost Index (ECCI) eased to 53.0% in November from 54.5% in October.

Wearable Electronic Fitness Devices Sales to Dip in 2015

Wearable electronic devices for fitness shipments are forecast to reach 68.1 million units in 2015, down from 70 million units in 2014, according to Gartner Inc. This temporary dip in sales will be driven by an overlap in functionality between smart wristbands, other wearable fitness monitors and smartwatches.

Global Market for Security Products at $25.28B in 2014

The total world production value of security products at factory gate prices was $25.28 billion in 2014. Of this, video surveillance products at $13.48 billion took a share of 53%, access control at $5.62 billion took 23% share and intruder alarms at $6.18 billion had a 24% share.

3D Printing Materials Market to Hit $8B by 2025

A massive increase in the use and applications of 3D printers is encouraging huge growth in the market for 3D printing materials. The total consumable market in 2013 was $800 million and is expected to reach $8 billion by 2025, according to IDTechEx's new report.

Personal 3D Printing Markets to See Significant Growth

The market for personal 3D printers looks vastly different than it did only a year ago. Market leaders have quickly expanded equipment offerings to fill out the entire market in an attempt to be everything to everyone.

Rapid Growth Witnessed in Medical Electronics Market

The medical electronics market is expected to grow at a rapid pace in most of the regions of the world due to growing income levels, and increasing prevalence of chronic and lifestyle disorders such as diabetes, hypertension, and cardiovascular diseases.

Smartphone Growth to Slow as Prices Drop

According to a new mobile phone forecast from the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker, worldwide smartphone shipments will reach a total of nearly 1.3 billion units in 2014, representing an increase of 26.3% over 2013.

Global Microsensor Market Sees Strong Growth

Growth in the consumer electronics, automotive, military, and healthcare industries is stimulating the global demand for different types of microsensors in these application sectors. The launch of technologically-advanced microsensors is also contributing positively toward growth in the global microsensor market.

NB PC Shipments to Overtake Tablets

According to preliminary results from the upcoming DisplaySearch "Quarterly Mobile PC Shipment and Forecast Report," in the third quarter of this year, the global notebook PC market grew 10% year over year, to reach 49.4 million units.

An Alternative Solvent with Low Global Warming Potential

by Rajat Basu and Ryan Hulse
HONEYWELL INTERNATIONAL

Abstract

In the past 20 years, the solvent industry has gone through a great deal of change. In the early 1990s, CFC-113 and 1,1,1-trichloroethane were the workhorses of the industry. The Montreal Protocol to phase out substances that deplete the Earth's protective ozone layer was implemented in the mid-1990s. After the phase-out of chlorofluorocarbon (CFC) solvents, the solvent industry fragmented into a variety of cleaning solutions. The electronics industry was a large user of CFC solvents, and many of these applications changed to aqueous-based cleaners. Some segments moved to chlorinated and brominated solvents such as trichloroethylene and n-propyl bromide. Other industries changed to no-clean fluxes. But those alternatives are now facing various problems: for example, aqueous-based cleaners use a lot of energy, require long drying times, use equipment that requires frequent maintenance, and require a large footprint. No-clean fluxes leave flux residues, and trichloroethylene and n-propyl bromide have toxicity issues. In response to these serious issues, newer solvents and blends are being introduced in the marketplace.

In this pursuit, the company developed a new low global-warming potential fluorinated solvent for precision cleaning. This solvent has a mosaic of properties that make it a good solution in the solvent domain. It is non-flammable, has low toxicity, environmentally friendly, and offers low surface tension, rapid drying, excellent solvency and a number of other favorable properties. In this article, we will review the properties and performance of the new solvent.

Introduction

The hunt for a new solvent to replace CFCs started in 1974, when UC Irvine Professor Sherry Rowland, and Mario Molina, a post-doctoral student in her lab, published[1] their work on the depletion of the Earth's protective stratospheric ozone depletion by CFCs and various halogenated compounds. Their findings were later confirmed by scientists around the world, especially the British Antarctic Survey in 1986. The British Antarctic Survey team discovered an ozone hole in the stratosphere over Antarctica,

which ultimately led to the Montreal Protocol[2] being ratified by the United Nations Environmental Program (UNEP) in 1987, which phased out CFCs around the world. Rowland and Molina received the Nobel Prize for Chemistry in 1995 for their discovery.

This discovery of stratospheric ozone depletion shocked the world and brought an end to CFCs' use as cleaning solvents, working fluids in refrigeration and air conditioning, foam expansion agents, and in various other applications. CFC-113 (1,1,2-trichloro-1,2,2-trifluoro-ethane) and 1,1,1-trichloroethane were previously used extensively in industrial cleaning. The PCB industry primarily used CFC-113 in cleaning solder fluxes and pastes after soldering and set the standards of cleaning for the boards. These solvents also found applications in metal degreasing, precision cleaning of aerospace components, cleaning of medical devices and in many other cleaning applications because of their high solvency for common soils, low toxicity, non-flammability and many other desirable properties. Since the phase-out of these solvents in 1996, the solvent market has become extremely fragmented, with industrial customers using many different solvents for each specific application.

No single solvent has been found that can be used effectively for as many applications in the same way as CFC-113 and 1,1,1-trichloroethane. In this article, we will discuss a new cleaning solvent and some of the successes it has had in cleaning. The chemical name of this new solvent is trans-1-chloro-3,3,3-trifluoro-1-propene. Using the numbering system of halogenated compounds[3] it can also be referred to as 1233zd(E); the E in parentheses indicates it is the trans configuration of the molecule. It has been found to be as good as CFC-113 in dissolving and cleaning most common soils, but it provides superior environmental properties.

"A large section of the PCB cleaning industry is using aqueous solvents and a number of water-soluble fluxes have also been introduced. However, aqueous cleaning has not been able to solve all the cleaning problems especially those in the defense and aerospace industries."

We will describe the properties and performance of this solvent in greater detail including its cleaning efficacy, environmental properties, stability under various conditions, along with its recovery by carbon adsorption and compatibility with plastics and elastomers, and compare them with some of the solvents used today.

Background

Cleaning technologies used today can be divided into a few major categories: solvent cleaning, aqueous cleaning, semi-aqueous cleaning, and not-in-kind, which include no-clean fluxes and supercritical cleaning, among others. Solvent cleaning includes various hydrocarbons, halogenated hydrocarbons, hydrofloroethers and several others, and blends of these materials with alcohols and other compounds. Aqueous cleaning refers to cleaning with water and various detergents; semi-aqueous refers to the removal of soils with terpene or citrus-based solvents and then washing these materials with water. None of these cleaning alternatives became a universal alternative to CFC-113 in cleaning. A large section of the PCB cleaning industry is using aqueous solvents and a number of water-soluble fluxes have also been introduced. However, aqueous cleaning has not been able to solve all the cleaning problems especially those in the defense and aerospace industries.

As technology in PCB design is advancing, line spacing is becoming narrower, components are being spaced closer to the boards, and more surface mount devices are being used. All of these factors are making cleaning PCBs more difficult, leaving a need for better solvents and technologies.

Now, going into some issues with existing technology, we can see that hydrocarbon-based solvents are flammable, which makes handling and use of such materials difficult. Semi-aque-

ous and aqueous cleaning technologies were initially favored to replace CFCs because of their lack of flammability, low price and availability. However, with the advances in PCB design, it has become apparent that the relatively high surface tension of water makes it difficult to penetrate in narrower spacing. The corrosive nature of water can also be problematic. In addition, drying is very energy-intensive and wastewater disposal brings in difficulty and expense in operation. In the case of semi-aqueous techniques, these same problems occur, in addition to odor and some flammability issues that users have to deal with.

Azeotropic mixtures of HCFC-225 (dichloropentafluoropropane) isomers and HCFC-141b (1,1-dichloro-1-fluoroethane) with alcohols were adopted by many users at the outset for defluxing and degreasing applications. They were actually drop-in substitutes for CFC-113. However, these compounds have lower ozone depletion potential than CFCs but are still not acceptable due to their non-zero ozone depletion potential. As a result, 141b was phased out in early 2000, and HCFC-225 isomers will be phased out starting January 1, 2015. Users have realized a need to adapt new technologies or new solvents to replace these materials. HFCs and HFEs are introduced; however, they do not have sufficient solvency to be used alone. A chlorinated hydrocarbon, tr-1,2-dichloroethylene, had to be added to these materials to boost their solvency, while alcohols have also been added to remove ionic contaminants.

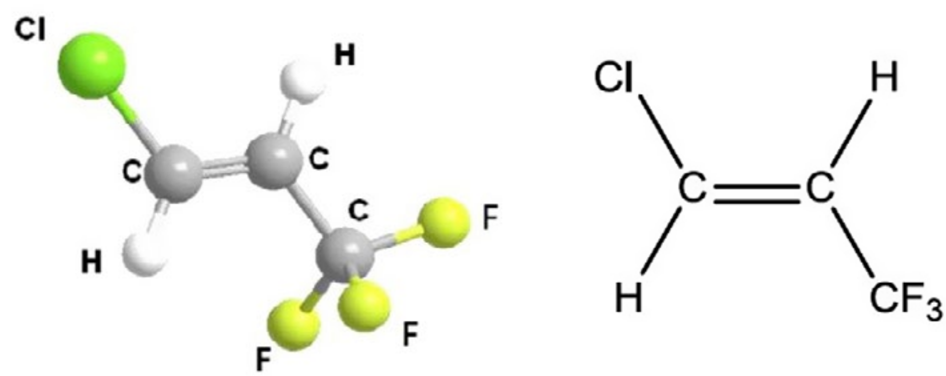
Among the not-in-kind technologies, the use of no-clean fluxes to avoid post-soldering cleaning altogether is worth discussing. Such no-clean fluxes with lower ionics are used by many people in the industry. While the use of such materials would in theory have eliminated the need for post-soldering cleaning altogether, it was found that for many applications, post-soldering cleaning is still required in order to preserve long-term reliability of the electronic components and to improve visual appearance of the boards by removing residues. As a result, it is common that no-clean fluxes need to be cleaned after soldering. Other technologies such as supercritical cleaning with CO_2, CO_2 snow, plasma cleaning technologies are also available in cleaning, but they are not generally used in defluxing applications.

With these challenges in the industry, the company recognized the need for better solvents and technology in cleaning and defluxing. A new generation of compounds, hydrochlorofluoro olefins and hydrofluoroolefins have been identified and developed for various applications including refrigeration and air conditioning, foam expansion agents and some solvent applications. The new 1233zd(E) is one such compound that is particularly well suited for solvent cleaning which we shall discuss below.

New Solvent Structure and Properties

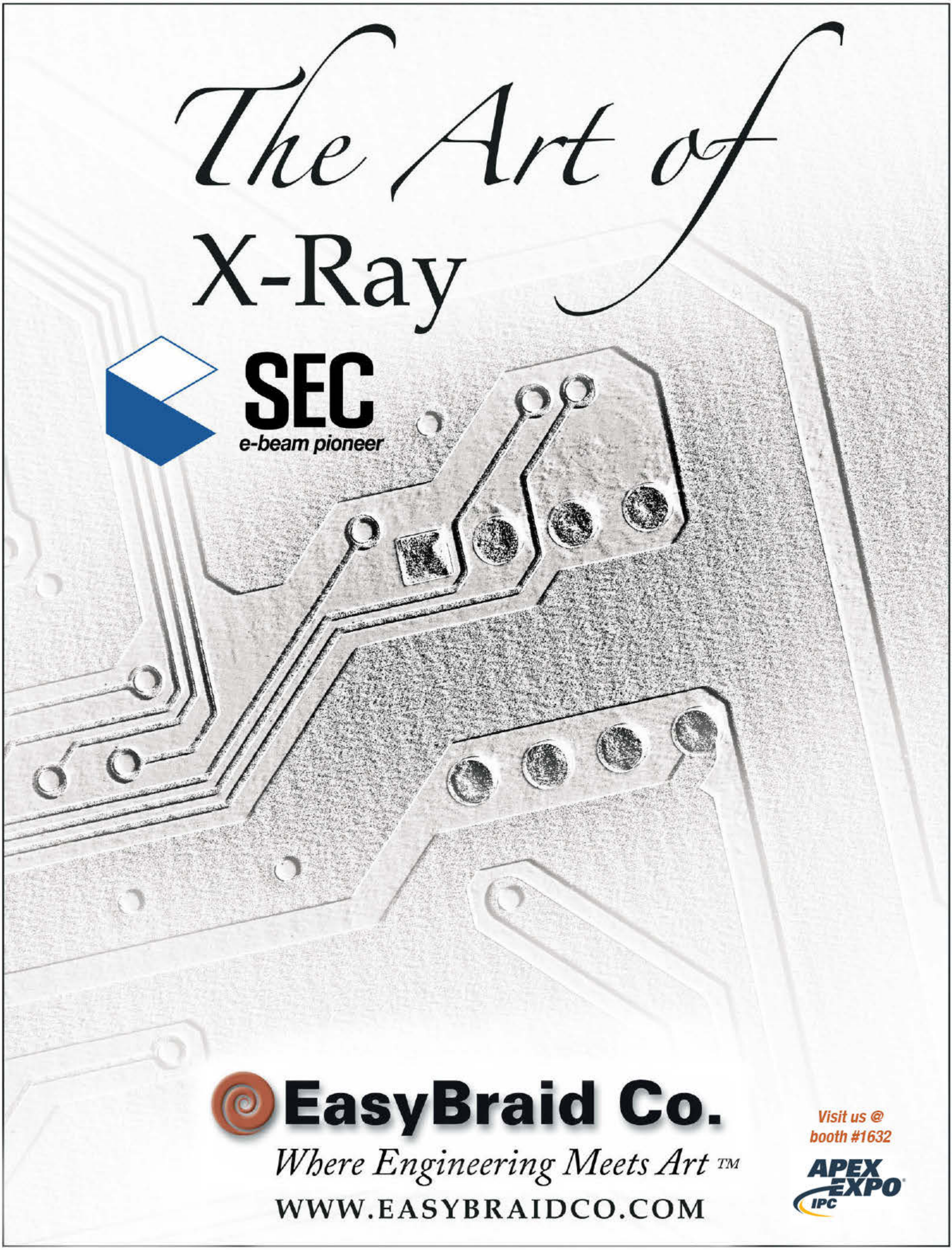
The molecular structure of this new solvent 1233zd(E) is shown in Figure 1.

A versatile next-generation solvent must satisfy a complex mosaic of properties. One of



- Molecular Formula: $CF_3CH=CHCl$
- IUPAC Name: (E) 1-chloro-3,3,3-trifluoro-1-propene
- Refrigerant Number: R-1233zd(E)
- Trans of E (entgegen) isomer

Figure 1: Chemical structure of solvent 1233zd(E).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the first considerations is its physical properties. A comparison of some of the physical properties of 1233zd(E) with CFC-113 and a few existing solvents used today, are shown in Table 1, where Perc is used as an abbreviation for perchloroethylene.

One seeming disadvantage of 1233zd(E) is its slightly lower boiling point as compared to many of the current solvent used in the marketplace. However, this sometimes turns out to be an advantage in certain applications because the cleaned parts will dry faster. Another advantage of 1233zd(E) is its high heat of vaporization, which does not vaporize very rapidly despite its low boiling point. So contrary to a perception that the solvent will readily evaporate at room temperature, it has been found that if one pours the solvent in a beaker at room temperature around 25°C, the solvent takes quite a while to evaporate.

Because of its higher vapor pressure, 1233zd(E) requires special shipping and handling instructions that are different from many of the existing materials. It will be shipped in a pressure-rated drum or cylinder. It also requires some changes to some existing cleaning equipment, but it can be nearly a drop-in substitute in some low emission degreaser incorporating minor modifications.

Besides being non-flammable, as evident by the lack of flash points, and no flame limits in air, 1233zd(E) also has a very low surface tension. 1233zd(E) has a surface tension of 12.7 dynes/cm which is the lowest among solvents shown in the Table 1. It has a Kauri-Butanol value of 25, providing it with a balance of penetration ability (low surface tension, compared to water at 72.1 dynes/cm) and solvent power (Kauri-Butanol (KB) value, compared to CFC-113 which has a KB value of 31) that makes it an excellent candidate to become the new environmentally friendly workhorse of solvents. The low surface tension of 1233zd(E) helps to make this compound excellent for use in applications where there is a need to penetrate narrow spacings and thus would be able to clean under surface mounts.

Environmental Properties

In today's world of environmental awareness and preferences for environmentally safe products, it is very important to discuss environmental properties of new chemicals. A comparison of 1233zd(E) environmental properties with that of several other solvents is provided in Table 2.

	1233zd(E)	HFC-43-10 mee[a]	HFE-7100[a]	HCFC-225	n-Propyl Bromide	Perc
Molecular Weight	130	252	250	203	122	165.8
Boiling Point C	19	54	61	54	71	121.3
Vapor Pressure psi @20 C	15.23	4.4	3.2	5.6	2.1	0.27
Heat of Vaporization KJ/Kg at BP	194	129.7	112.4	145	144.7	207
Flash Point C	None	None	None	None	None	None

Table 1: Selected physical properties of solvents. (HFCs and HFEs are mostly used in blends with Tr-1,2-dicholoroethylene or other substances, so their values in this table are not representative of material used in practice.)

Table 2 shows that 1233zd(E) has significantly low global warming potential (GWP) compared to most other solvents used for various cleaning applications. Compounds which have a lower lifetime have lower GWPs since they do not stay in the atmosphere longer, absorbing infrared radiation to make earth warmer. The lifetime of the compound, GWP and ozone depletion potentials for 1233zd(E) have been determined by world renowned scientists[5].

Volatile Organic Compound Characterization

Certain chemical compounds are labeled as volatile organic compounds (VOC), depending on whether they are found not to be photochemically reactive to producing smog at the lower atmosphere, hence characterized as a non-VOC chemical compound. This is measured by an experimentally determined number called maximum incremental reactivity (MIR). To be non-VOC, a chemical has to have an MIR less than the MIR of ethane (0.27 gms of ozone produced/gm of VOC). The MIR of 1233zd(E) (measured value, 0.04[5]) is well below that value. The U.S. Environmental Protection Agency has taken final action to revise regulatory definition of VOC for purposes of preparing state implementation plans to attain the national air quality standards for ozone under Title 1 of the Clean Air Act. This final action adds 1233zd(E) to the list of compounds excluded from the regulatory definition of VOCs on the basis that this compound makes a negligible contribution to tropospheric ozone formation. It is published in a recent Federal Register publication[7].

As a result, if someone is subject to certain federal regulations limiting emissions of VOCs, their emission of this compound need not be regulated if they use this solvent for cleaning applications. This action may also affect whether 1233zd(E) is considered as a VOC for state regulatory purposes, depending on whether the state relies on the EPA regulatory definition of VOCs. 1233zd(E) is now going through review of VOC status in California.

In case of HFCs and HFEs, they are considered individually non-VOCs but most of the solvents sold today in the marketplace based on HFCs and HFEs are essentially blends with tr-1,2 dichloethylene and are therefore labeled as VOCs because of VOC designation of tr-1,2 dichloroethylene.

Property	1233zd(E)	HFC 43-10mee	HFE-7100	HCFC-225	n-propyl bromide	Perc
Atmospheric Life	26 days	17.1 yrs	4.1 yrs	2.1/6.2 yrs	16 days	111 d
ODP	~0[a]	0	0	0.03	0.002-0.03	0
GWP_{100}	1	1700	320	180/620	N/A	10

Table 2: Environmental properties of selected solvents.
[a]No impact on ozone layer depletion and is commonly referred to as statistically zero (Wuebbles[4]).

Property	1233zd(E)	HFC 43-10mee	HFE-7100	HCFC-225	n-propyl bromide	Perc
Atmospheric Life	26 days	17.1 yrs	4.1 yrs	2.1/6.2 yrs	16 days	111 d
ODP	~0[a]	0	0	0.03	0.002-0.03	0
GWP_{100}	1	1700	320	180/620	N/A	10

Table 3: Volatile organic compound (VOC) designation of selected solvents.

	1233zd(E)	HFC 43-10 mee	HFE-7100	HCFC-225	n-propyl bromide	Perc	Tr-1,2 DCE
Permissible Exposure Limit	800[(a)]	200[(b)]	700[(c)]	25[(d)]	10[(f)]	25[(e)]	200[(e)]

Table 4: Toxicity properties of selected solvents.
[(a)]Company OEL (Occupational exposure limit)
[(b)]DuPont AEL (Acceptable exposure limit)
[(c)]3M Occupational AEL
[(d)]Asahi Glass AEL
[(e)]ACGIH Threshold Limit Value (TLV)
[(f)]Current ACGIH TLV, a significantly lower value has been proposed and is under consideration

Safety Aspects

1233zd(E), being completely non-flammable and having no flash point or upper or lower explosion limits, requires no specific explosion proofing like some other solvents. Toxicological test data for the solvent have also been completed and the company Occupational Exposure Limit (OEL) of 800 ppm (8-hour time weighted average) has been assigned to 1233zd(E). Table 4 compares the occupational exposure limits of several solvents. All values quoted below are 8-hour time-weighted-average exposure concentrations.

Solubility with Oils

We will now describe the cleaning performance of 1233zd(E). To start, we compared the solubility of various materials which may be considered as soils to be cleaned in 1233zd(E) in Table 4 and then the cleaning test results are shown in Table 5. The miscibility test was done where equal parts of solvent and oils are mixed together and visual observation was made to see if the soils and the 1233zd(E) remained in a single phase, indicating that the soils were completely dissolved in the solvent. In all cases the solvent looked clear and the mixtures are reported as miscible in Table 5. The purpose of the study is to test how well the solvent performs in dissolving various soils.

Table 5 shows that 1233zd(E) has miscibility properties similar to n-propyl bromide and AK-225 solvents which are good solvents and are currently used by a number of users in a wide variety of applications. All of these oils in Table 4 were found insoluble in pure HFCs and HFEs and require the addition of a co-solvent such as tr-1,2 dichloroethylene. So in summary 1233zd(E) has solvency characteristic as good as the current solvents for most common soils.

Soil	1233zd(E)
Mineral Oil	Miscible
RMA Solder Flux	Miscible[a]
Refrigerant oil	Miscible
Silicone Lubricant	Miscible
Lapping Compound	Miscible
Cutting Oils	Miscible

Table 5: Soil dissolution in 1233zd(E).
[a]In case of RMA solder flux, a blend of 1233zd(E) and methanol was used.

Cleaning Ability for Oils

In the next step, we evaluated how good the solvent is at cleaning parts soiled with oils. In these tests, we soiled small 2" x 1" stainless steel coupons with various commercial oils used in the field. The coupons were immersed in boiling 1233zd(E) for 2 minutes and dried in the solvent vapors. This test was performed in small beakers with condenser coils near its lips which emulated conditions similar to a lab va-

Test Soil	% Removed	Test Soil	% Removed
Vacuum pump oil	99.7	Mil-PRF-83282	100
Cutting oil	99.3	Mil-PRF-C-81309	98.8
Silicone oil	99.4	VV-D-1078	97.7
Mineral oil	99.8	Nye oil 438	72.4

Table 6: Soil removal from coupons using 1233zd(E).

por degreaser. Coupons were visually observed for cleanliness and weight changes of the coupons were also noted. Cleaning results are given in Table 6, showing that it removed the soils from stainless steel coupons quite well for almost all the oils except for one. This demonstrates good degreasing efficacy of the solvent 1233zd(E).

Defluxing Performance

We also conducted a defluxing study with 1233zd(E) and methanol blend. The blend used is an azeotropic blend of 1233zd(E) and methanol so they would not segregate in a vapor degreaser. Small pieces of metal coupons with baked solder fluxes were immersed in solvent for two minutes and dried in the vapor. The experimental set-up is same as mentioned before boiling solvent in beaker with condenser coils near the lip. A commercial solder was used in this test. Test results showed that the removal was good both by visual observations and gravimetric analysis. It showed equal or better performance compared to another commercial solvent/alcohol blends.

There are a number of RMA fluxes that have been cleaned with this 1233zd(E) and methanol blend in a vapor degreaser. These fluxes were deposited on commercial parts and then removed in a vapor degreaser using immersion and vapor rinse. The fluxes cleaned are given in Table 7 below.

It has been found that the 1233zd(E)/methanol blend is not very effective in cleaning some of the no-clean and rosin cure fluxes. Efforts are underway to develop 1233zd(E) based solvent blends to clean these no-clean and rosin core fluxes and pastes.

RMA Fluxes removed	
Kester 125	Kester 185
Kester 1544	Kester 48
M705-GRN 360 MZ	Kester 197

Table 7: RMA Fluxes/pastes cleaned in 1233zd(E) and methanol blend.

1233zd(E) and alcohol blend has also shown promising results in tests as a cleaner in defluxing with aerosol spray cleaning applications[6]. Aerosol spray is generally used in a number of cases especially for rework. Here the solvent blend is used in conjunction with a propellant and sprayed onto fluxed printed circuit boards. Visual observation was made, circuit boards looked visually clean and gravimetric measurements confirmed the removal of flux from the boards.

Shipping and Handling

Due to the higher vapor pressures and the lower boiling point of 1233zd(E) shipping and handling of solvent will be different. Solvent will be shipped in steel cylinders like refrigerant jugs with outlets fitted with liquid and vapor valves. The jugs will be under the vapor pressure of the solvent itself. Containers will be of different sizes one gallon, five gallon and higher quantities such as near one barrel size or bigger depending on customer needs. The containers are recommended to be stored under room temperature conditions.

Degreaser Studies

Looking at the boiling point of 1233zd(E) some users initially expressed concern that the

solvent might evaporate out of a vapor degreaser. We ran several degreaser trials to better understand how 1233zd(E) behaves in a degreaser and what kind of changes in design may be needed to the degreasers, if any.

Our test results showed that with a few modifications a typical degreaser can be run with very low loss rates with 1233zd(E). The major requirements for the degreaser are that it has both primary and secondary coils (free board coils). The operating condition of the coils may have to be modified. The primary coils should be operated at around 0°C and secondary coils should operate at about -20°C. Low emission vapor degreasers manufactured by most vapor degreaser manufacturer can be operated at these conditions. With these operating conditions we found the solvent loss is equivalent to that of other solvents that are currently run in low-emission vapor degreasers.

Since the solvent will be shipped in containers such as refrigerant jugs, solvent will be charged and discharged through a closed-loop system. It is also recommended that centrifugal pump to recirculate the solvent be located near the bottom of the rinse sump to avoid cavitation or a non-cavitating pump such as a diaphragm pump can be used.

Older degreasers with no secondary coils have to be retrofitted with a set of secondary coils and in some cases circulation pumps may have to be changed in order to avoid cavitation. Some other retrofits have to be performed on a case-by-case basis.

Stability Studies

The chemical stability of 1233zd(E) with and without the presence of water, with metals and fluxes, is another important factor to be considered in the identification of a next-generation solvent. To test this we used a set-up shown in Figure 2. Chilled water-cooled condensers were connected to small flasks and the solvents were boiled in the flasks and refluxed back to the flask. This test continued for two weeks.

In the test, solvent is boiled with water alone and in the presence of various metal coupons such as stainless steel 304, cold-rolled steel, galvanized steel, copper, aluminum, monel, inconel and titanium. The coupons were partially immersed in the solvent which allowed us to look at the state of the coupons at the interface of liquid and vapor. At the conclusion of the test the coupons were observed visually for rusting or pitting and the remaining solvent in the flask was examined for breakdown products including chlorides and fluorides which are good indicators of breakdown of solvent. Tests showed that there was no increase of chlorides and fluorides in the solvent over the baseline and no other degradation products were formed indicating that the solvent is quite stable under these conditions. The test coupons also showed no rusting or pitting. Similar tests also continued with addition of solder flux in the liquid and in that case also solvent showed excellent stability under these adverse conditions.

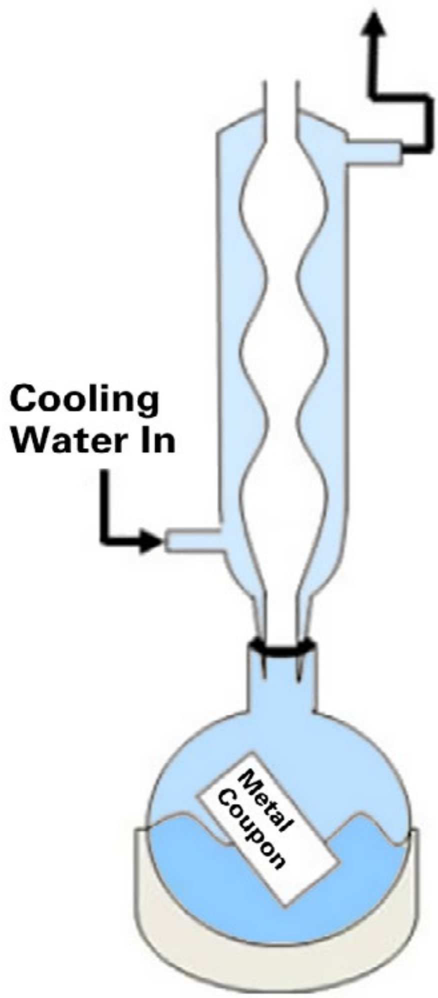
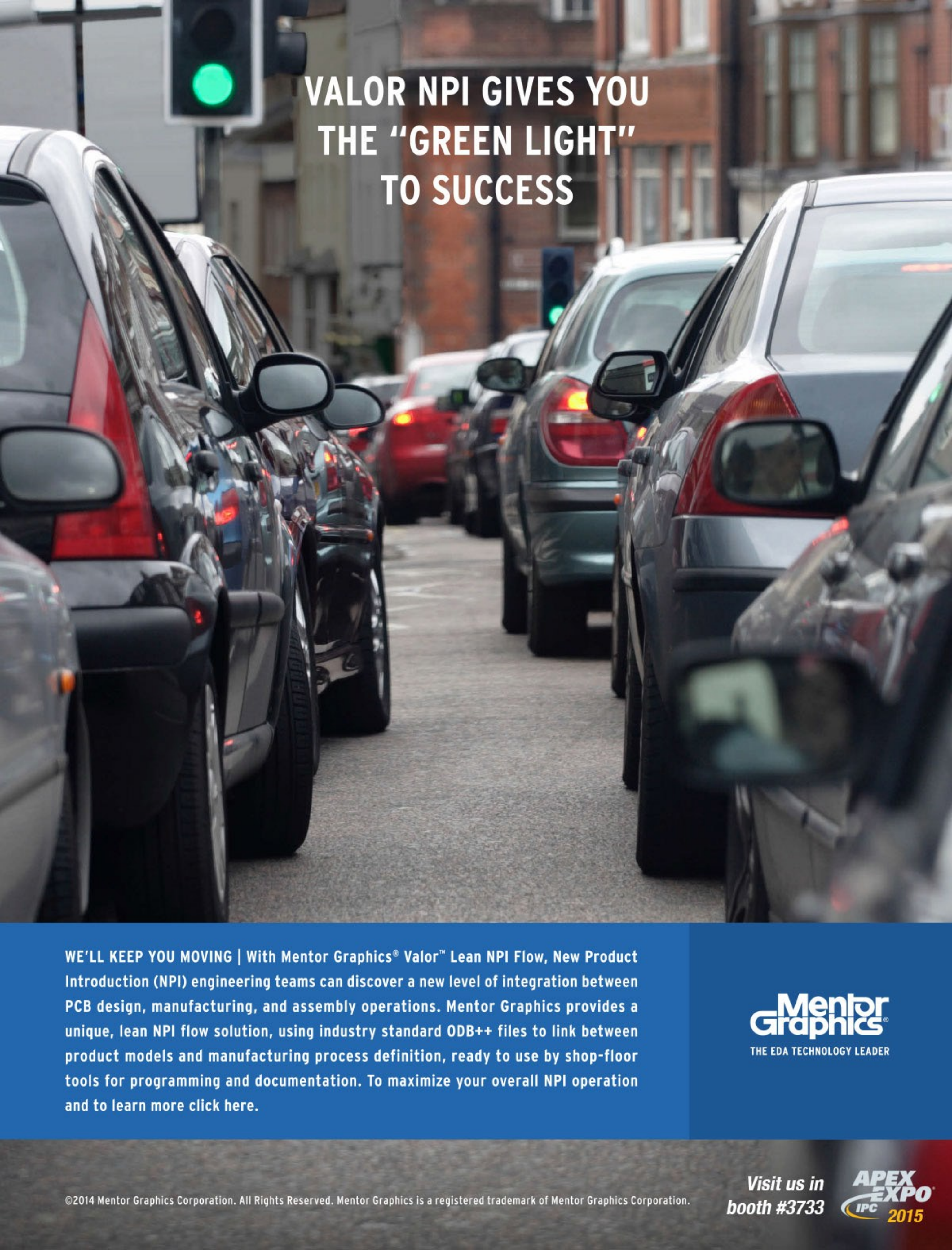


Figure 2: Reflux test study set-up.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The important thing to note is that the solvent does not turn acidic, a problem seen with some solvents such as n-propyl bromide or tr-1,2-dichloroethylene.

This test essentially simulates the condition in a vapor degreaser, and as such suggests that it is unlikely that the solvent will break down in use in a vapor degreaser.

Solvent stability is also studied in recovery with carbon adsorption. The tests were done by an outside agency and showed no breakdown of solvent in adsorption and desorption with activated carbon. 1233zd(E) is found to be compatible with carbon recovery unlike some HFCs and HFEs.

Compatibility with Plastics and Elastomers

Compatibility of common plastics and elastomers were studied in 1233zd(E). Commonly used plastics, such as acrylonitrile-butadiene-styrene (ABS), high-density polyethylene (HDPE), nylon, polycarbonate, polypropylene, polyethylene terephthalate, poly-vinyl chloride, high-impact polystyrene, and acrylic were immersed in the solvent for two weeks at room temperature in enclosed cells. At the end of the two-week exposure, the coupons were taken out and weight and volume changes were recorded. Except for high-impact polystyrene and acrylic all other plastics have minimal or no effect. 1233zd(E) completely dissolved acrylic material.

Similar tests were performed with elastomers. Elastomers used in the compatibility test are fluoroelastomer (Viton®B), epichlorohydrin rubber, Buna N (nitrile butadiene rubber), butyl rubber, buna-nitrile, polyurethane 390, neoprene, silicone rubber, perfluoroelastomer (Kalrez®) and ethylene propylene diene M-class (EPDM) rubber. Here, weight change and dimensional change were carried out along with visual observation for cracks or other degradation. Significant changes were observed for Buna-nitrile, EPDM and for others the changes observed are minimal.

With a vast array of plastics and elastomers in the marketplace it is not possible to test all kinds and grades of plastics and elastomers in our own labs. So, users are advised to test compatibility prior to using the solvent.

Conclusions

In this article, we have described the characteristics of the new solvent 1233zd(E) or trans-1-chloro-3,3,3-trifluro-1-propene, which showed excellent promise as a solvent for defluxing and other cleaning applications. It has better environmental and toxicity properties compared with many other solvents in the marketplace today and can be used in vapor degreasers. It is also a stable, non-flammable product with reasonable compatibility with materials. Presently, 1233zd(E) registration for solvent and other uses is underway in many countries. **SMT**

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Kitron Nets Order from Offshore/Marine Sector
"Kitron has experienced a reduced order backlog within the Offshore/Marine sector during 2014, which makes this order important in order to secure volume going into 2015," said Peter Nilsson, CEO.

Orbit Electronics' New Orders in November Top $1.4M
Orbit International Corporation, an EMS and software solution provider, announces its Electronics Group received new and follow-on orders for its products on several programs in the month of November totaling over $1,400,000.

API Wins $3M Order for Secure Communication Products
API Technologies Corporation has received a new $3 million order from a Fortune 50 company to produce secure communications products that will be used to support a U.S. C4ISR program.

Vintage Nominates Directors to IEC's Board
Vintage Capital Management, LLC has filed preliminary proxy materials with the Securities and Exchange Commission for the election of seven directors to IEC's Board of Directors at its 2015 Annual Meeting of Stockholders.

BAE Systems to Buy Eclipse Electronic Systems
BAE Systems has entered into an agreement with Esterline Corporation for the proposed acquisition of its wholly-owned subsidiary, Eclipse Electronic Systems, Inc., for cash consideration of approximately $28 million, subject to closing adjustments.

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Questions hang heavy in the air about India relations with its traditional military suppliers such as Palestine, Russia, and the U.S. as the country inches closer to buy more and more military hardware from Israel.

Q4 Global Defense Business Confidence Report
Research and Markets has announced the addition of the "Defense Business Confidence Report Q4 2014" report to their offerings. This report globally analyzes industry opinions on the latest economic and customer issues, and their impact on investment decisions and growth prospects within the defense industry.

Global Business Aviation Reaches Cruising Altitude
Global business aviation activity saw modest gains in Q3 2014, with 2% growth quarter-over-quarter and 2.2% growth year-over-year, according to JSSI's most recent Business Aviation Index.

Military Radar Market Continues on Growth Trajectory
"The total number of radar shipments is forecast to grow at a CAGR of 4.1% through 2023 to reach 1,393 units," notes Eric Higham, North American director for ADS.

COLUMN

SMT QUICK TIPS

How to Select a Stencil Printer

by Robert Voigt
DDM NOVASTAR

Editor's Note: SMT Magazine welcomes new columnist Robert Voigt, who will help folks analyze and select SMT equipment for the PCB business, beginning with stencil printers. Future columns will walk potential buyers through the entire cycle of assembly equipment, including new technologies.

What is a stencil printer? The first step in a paste, place, and reflow assembly operation is the stencil printer, which can be manual, semi-automatic, or automatic. This machine dispenses solder paste which, using a squeegee, is forced over the openings in a stencil onto a printed circuit board.

Production Volume

The first question to answer is: What production range are you dealing with? Knowing this will help you to decide what level of automation you'll need.

- Up to 150 boards/day indicates a manual system, and will likely run about $2,000–$5,000 for a decent new machine
- Up to 500 boards/day is in the semi-automatic range, and will command in the range of $8,000–$14,000
- More than 500 boards/day is in the fully automatic range, and can cost $30,000 or more, depending on the bells and whistles that come with it

Manual Systems

Here, speed is typically not a big issue. Fine pitch and accuracy are the most important factors. Accuracy is determined by how securely aligned the circuit board is in the machine. There are four dimensions to consider for the control method: X, Y, Z and Θ.

Once the board is aligned in the machine, paste is applied using a squeegee. While there are typically a couple of options on all systems,

most assemblers will be using a manual squeegee. Some machines have a built-in guide that aids in applying the right amount of solder paste. There are several key points to applying paste properly:

- Angle of attack
- Squeegee pressure
- Squeegee speed

Once the paste is applied, the stencil is lifted off the circuit board, either vertically, or pivoted. There is no practical difference in either of the two lift methods.

Semi-automatic Systems

In a moderately high-volume environment, several of the functions can be automated to some extent, making the process more efficient, more repeatable, and allowing a higher yield at lower cost. The following are typically found in semi-automatic stencil printers:

- Auto open/close for board loading and unloading, which can reduce operator fatigue
- Controlling the squeegee pressure
- Controlling the movement and speed of the squeegee
- Visual alignment/assist options to facilitate positioning

Fully Automatic Systems

In fully automatic systems, everything is managed without operator intervention. Systems may include automatic board loading/unloading and auto fiducial alignment for X, Y, Z and Θ positioning. Again, you get what you pay for. If you're running 2,000 boards/day, more automation may provide significant dividends in terms of quality yield, reduced labor costs, and more control over your process. If you're spending the kind of money a fully automatic system commands, you will need to perform some serious due diligence on special capabilities that can't be covered in a short article.

Construction

Regardless of the volume, you're looking for the best accuracy and repeatability you can get, so once fixturing is set up, you don't want to waste time recalibrating. Accuracy and repeatability are directly related to fine-pitch capability, and pitch accuracy is directly related to machine stability. For this reason, construction of the holding plates is critical. Machines constructed with sheet metal are not nearly as stable as those made using a machine-ground holding plate with welded frames. This assures that nothing moves from one board to the next so you can expect repeatable accuracy from board to board.

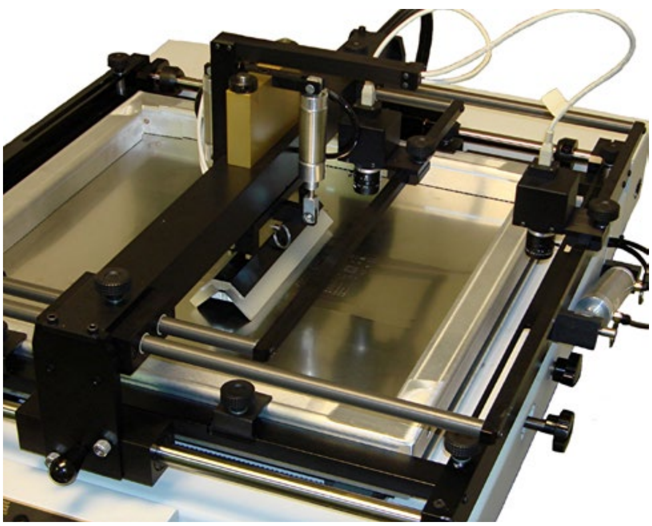

Figure 1: Adjustable camera on vision machine.

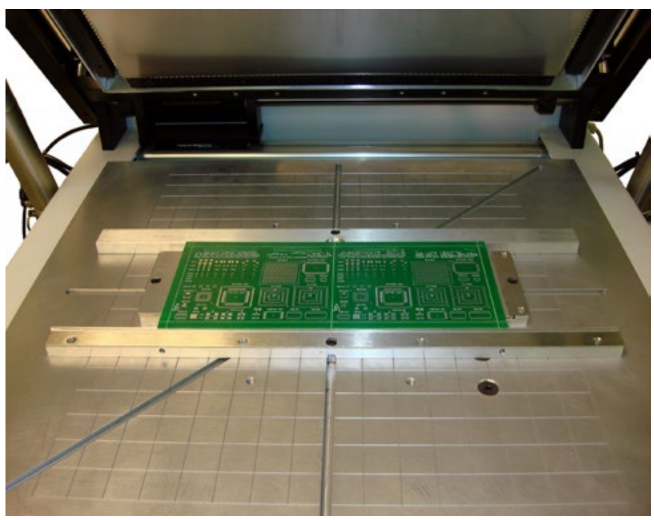

Figure 2: Machine-ground holding plate.

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Figure 3: View of squeegee.

Speaking of boards, an obvious consideration is the board size that the machine will accommodate. If you are running a number of different boards of varying sizes, be sure the stencil printer can handle your largest size. Machines can vary among manufacturers, accommodating board sizes from as small as 1" square to as large as a square meter or more, so make sure your equipment provider can handle your specific needs.

Another factor affecting print quality is the squeegee type. Squeegee blades are made from several materials and come in a variety of sizes. Blade types are commonly urethane, metal (most popular), and plastic. Metal squeegee blades typically enable a more controlled print height across the board and work well with a mix of component sizes.

Some users consider the stencil printer to be the most important purchase of all—consider this quote from the Adafruit forum:

Spending money on a good stencil printer is a really good idea. You live and die by the quality of the solder paste deposit on your PCB.

Vendor Support

One of the most important aspects of this evaluation (for any SMT machine, frankly) will be support, and the best way to learn how a company treats its customers is by word of mouth. Talk to several customers to find out how happy they are with the machine, the seller, and the support they provide. Where is the manufacturing plant? Can they help troubleshoot software or alignment issues over the phone? Do they offer field service? Do they have spare parts in stock for immediate shipment? Remember to ask your supplier about their older machines in the field, and if down the road, spare parts are available, and about their capability to customize a spare part if the machine becomes obsolescent. Ask what the expected life-cycle of the product is. The industry standard is seven years. Remember, there is a difference between a true manufacturer and an equipment supplier or distributor.

Double-sided Boards or Flexible Circuits?

Do you need a method to print both sides of the board? Check to see that the model you're considering offers a double-sided nesting fixture or vacuum fixture to hold down flexible circuits.

Ease of Use

Every stencil manufacturer makes different size frames. The stencil printer you buy should be able to accommodate various size mounting frames and/or tubular frames. The manufacturer should also be able to provide adapters for frameless stencils.

Don't overlook electrical requirements. Make sure the machine you buy will plug-and-play in your environment without pull-

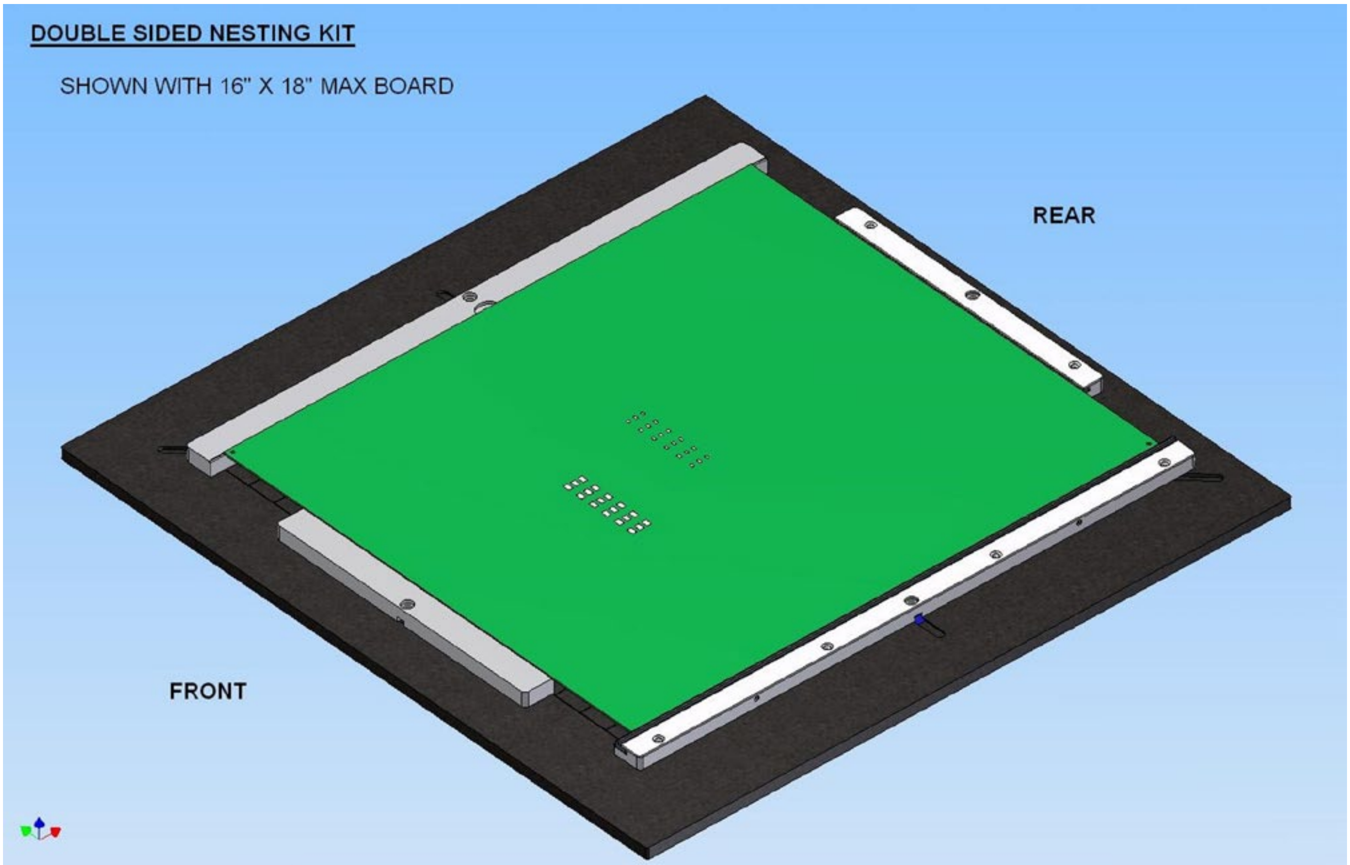

Figure 4: Double nesting kit.

ing in new wiring or else plan on an adapter/transformer.

Remember: The application of your solder paste is the start of your process. It has to be right because the rest of the process can't make up for improper solder placement.

Next month: pick-and-place machines! **SMT**

Robert Voigt is VP of global sales at DDM Novastar Inc. He may be reached at rvoigt@ddmnovastar.com.

Transparent Transistors Nearing Commercialization

Materials first developed at Oregon State University more than a decade ago may be about to shake up consumer electronics.

Transparent transistors were invented by OSU researchers in 2002. One of the most important of the semiconductors is based on indium gallium zinc oxide, or IGZO.

"Amorphous oxide semiconductors appear well-positioned to significantly impact a $100 billion industry," said John Wager, holder of the Michael and Judith Gaulke Chair in the OSU School of Electrical Engineering and Computer Science.

Transistors made using IGZO consume much less standby power. Cell phones might be created that only need charging once or twice a week.

SMT007 Supplier/New Product News Highlights

Ellsworth Adhesives Earns ISO 9001:2008 Certification

The company announces its Spain, France, and Germany facilities are now certified to ISO 9001:2008 for the distribution of adhesives and associated application equipment, and specialty repackaging of adhesives and resins.

Weller, Circuit Technology Enter Strategic Partnership

Weller announces a new partnership with Circuit Technology Inc. (CTI), a representative organization specializing in PCB assembly and repair equipment including placement, reflow, inspection, soldering, rework, and hand tools, to provide enhanced training support for all Weller equipment.

Dymax Releases Model 455 Micro-Spray Valve

The company has released a more precise, flexible, and easier-to-use Model 455 Micro-Spray Valve. It features an inert, 100% disposable fluid path which carries materials from the material reservoir to the spray nozzle in a sealed path. This prevents materials from coming in contact with the valve's inner components and ensures a contaminate-free dispensing process.

P. KAY Metal Expands MS2 Solder to Mexico

The company has announced the issuance of a new expansion of its MS2 solder dross elimination patent in Mexico. This is the second patent granted for this product and even more important, process in Mexico. The use of liquid dross recovery materials in an off-line process has been added to the claims which now exactly duplicate the previously granted U.S. patent.

LPKF Launches New Model in Fusion3D Series

The latest model in the Fusion3D series extends LPKF's family of high-performance laser systems for laser direct structuring (LDS) once again. For this technology, a laser system applies conductor structures to three-dimensional plastic parts. Metal tracks then form on these structures.

Essemtec Names Test & Rework Solutions Rep

With immediate effect Test & Rework Solutions (Pty) Ltd. has become Essemtec's official representative and distributor throughout South Africa.

Intertronics Releases New DYMAX 3401

Explained Peter Swanson, M.D. of Intertronics, "Dual-cure 3401 cures rapidly and reliably under UV with low shrinkage and is moisture and thermally resistant. Post process it fluoresces blue under low intensity black light for easy inline bond inspection."

Nordson Advanced Technology K.K. Japan Relocates

Nordson Corporation announces that Nordson Advanced Technology K.K. Japan has relocated to new, larger facilities in Tokyo to deliver superior sales, service, technical training, and support to its customers.

JAVAD EMS Adds New Nordson YESTECH AOI System

JEMS began working with Nordson YESTECH in 2009, implementing an F1 AOI system and later trading it in for the new FX model. Today, JEMS has four FX AOI systems on the production floor of its San Jose, California facility.

Dymax Debuts Guide to Light-Cure Conformal Coatings

Dymax Corporation's new Guide to Light-Cure Conformal Coatings outlines the benefits of using light-cure conformal coatings as well as cost justification, typical processing guidelines and best practices, product selection criteria, data, and industry specifications.

Stencil Printing in PCB Cavities

by Rachel Miller-Short
PHOTO STENCIL LLC

December's Short Scoop presented results from the first part of a study to determine if a 3D electroform stencil, in just one printing step, could be used to print both levels of a two-level board with cavities. The study explored two different printing modes: step print and reservoir. In the first part we examined the step mode. The results confirmed that a 3D electroform single thickness stencil could indeed print solder paste for a .3 µm µBGA with pads on two levels of the PCB separated by 7 mils (175 µm). It also showed that the squeegee blade used in the printer makes a significant difference in the application of the solder paste and the results obtained.

Here we explore whether a single-thickness electroform stencil can print flux or solder paste into a recessed area on a PCB for an embedded flip-chip with a cavity depth of 14 mils (350 µm), which is becoming a requirement for many components. Normally, to print on both levels requires special stencil and squeegee blade designs. A two-step stencil process is often used. We wanted to see if one stencil could be used instead. Using just one stencil to print both levels at the same time saves time, money, and resources.

Board, Stencil, and Squeegee Blade Set-Up

To test whether we could print into a recessed area, a reservoir was created on the front side of a PCB by gluing a 356 µm (14 mil) thick shim on the flex circuit. Flip-chip pads were embedded in the cavity. The shim was pin registered to the flex and then glued in place.

For the stencil, we used a 2 mil (50 µm) thick 3D electroform stencil with a 14 mil (355 µm) deep pocket and apertures consisting of 10 mil (250 µm) circles.

The stencil was grown on a mandrel with pocket walls that were machined at 45°. The stencil had three separate flux reservoir cavities with different aperture sizes: zone 1 had 4 mil (100 µm) apertures, zone 2 had 4.5 mil (112 µm) apertures, and zone 3 had 5 mil (125 µm) apertures.

For reservoir printing, the squeegee blade of choice is either a contained head pump-print system or a pump-print rubber blade. Our tests tried a 90° rubber blade, a metal blade, and a pump-print rubber blade.

Both flux and solder paste were printed into the cavity. The solder paste was an Alpha type 6 LV dispense. The viscosity of this solder paste

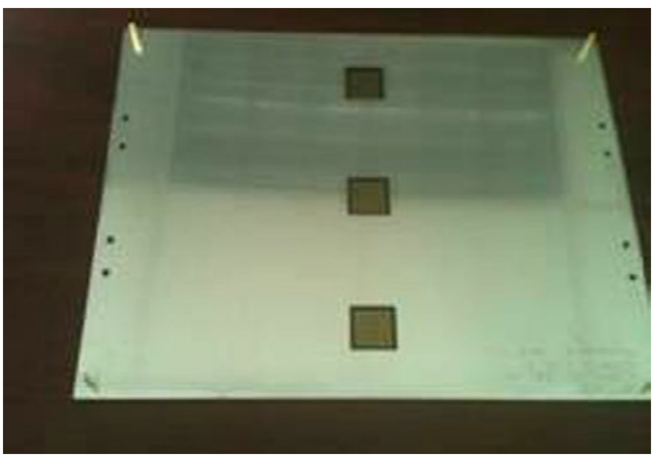

Figure 1: PC cavity created by glued shim.

Figure 2: 3D electroform stencil, 2 mil thick with 14 mil deep cavity, and laser-cut apertures.

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Kauai, Hawaii

Microelectronics Symposium

Featured Keynote Speakers

Required Packaging Technologies for Cognitive Computing Devices

Yasumitsu Orii
IBM Corporation

Trends of 3D IC/3D Packaging for Mobile & Wearable Electronics

Shen Li Fu, Ph.D.
I-Shou University

Advanced Integration Technologies for Cyber Physical Systems

Klaus-Dieter Lang, Ph.D.
Fraunhofer IZM

Big Data in Health Care and Biomedical Research

John Quackenbush, Ph.D.
Harvard School of Public Health

Patient Connected Health: The Digital Domain

Matthew Hudes
Deloitte & Touche

In-situ Control Systems in Manufacturing

Horatio Quinones, Ph.D.
FDCS LLC

smta.org/panpac

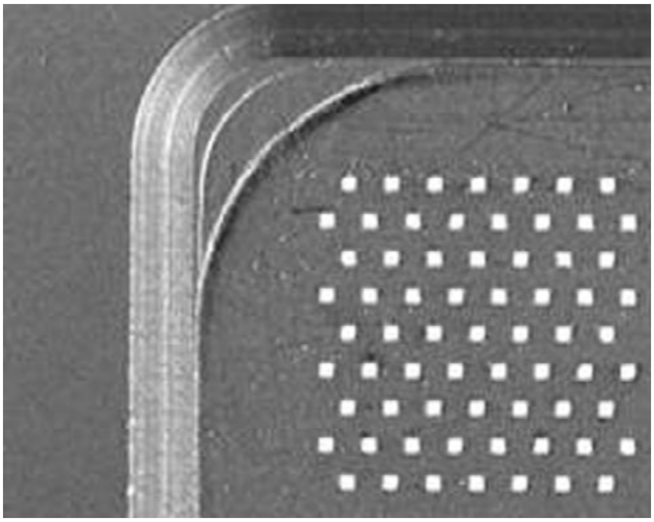


Figure 3: Close-up of cavity with apertures.

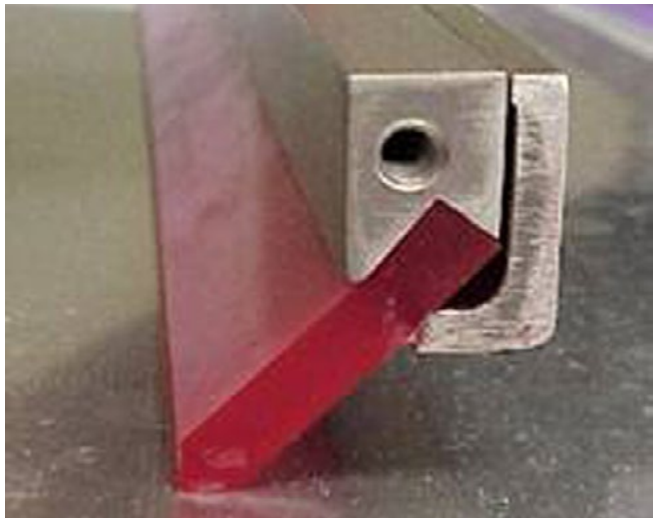


Figure 4: Pump-print rubber squeegee blade.

was about the same as the high-viscosity flux (~300 poise).

Five different types and viscosities of flux were used:

Type	Viscosity Poise
Indium 3600	160
Indium 676	200
Alpha 353 Black	<150
Alpha 390	140–250
Alpha 338	250–350

The printing pressure applied was 1.5–6 kgm for a 12" blade with speeds of .12 mm/second to 150 mm/second. There was a dry wipe after each print. After printing, the boards were inspected by a solder paste inspection system.

Print and Inspection Results

The results show, as with step mode printing, that the type of squeegee blade used makes a difference.

- Metal squeegee blades did not apply enough downward pressure to transfer flux or solder paste through the 100 µm (4 mil) square apertures onto the recessed flip-chip pad sites
- Rubber squeegee blades with a square edge were also ineffective in transferring flux or paste
- The pump-print rubber squeegee blade applied sufficient uniform pressure over the reservoir to achieve good transfer of flux and solder paste to the pad sites
- A self-contained print head squeegee system (although not available for this testing) most likely would also provide uniform pressure over the reservoir resulting in good transfer of flux or solder paste to the pad sites

One problem we encountered was that the flux was too transparent to the laser optics of the solder inspection machine to measure flux volume. It was also difficult to distinguish the pad from the flux deposit because of the flux transparency. However, we were able to construct a reservoir cavity 356 µm (14 mil) deep over a blank FR-4 PCB to view flux deposits on a clean surface. Examination of the boards showed:

- The lowest viscosity flux (160 poise) gave the poorest results. Flux deposits were left on the flex circuit pads and there was flux bleed at the trailing edge of the squeegee stroke
- Alpha 338 with a viscosity of 250–350 poise worked the best. This was the highest viscosity flux for the group of fluxes tested

STENCIL PRINTING IN PCB CAVITIES *continues*

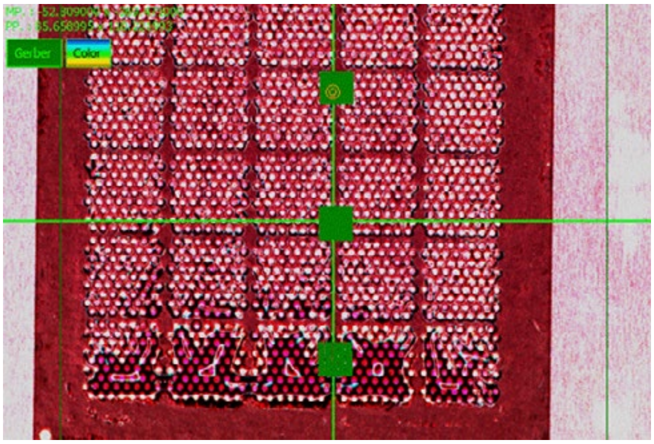


Figure 5a: Flux deposits on flex flip-chip pads using 160 poise viscosity flux (front-rear squeegee direction).

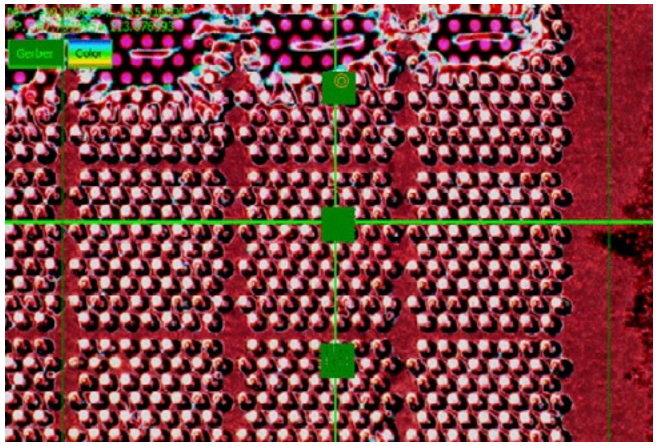


Figure 5b: Flux deposits on flex flip-chip pads using 160 poise viscosity flux (rear-front squeegee direction).

- Type 6 low viscosity (300–400 poise) dispensing solder paste also worked well for reservoir printing

Figures 5a and 5b show the flux deposits on the flex circuit pads for the lowest viscosity flux (160 poise) for the forward and reverse squeegee stroke. There is flux bleed at the trailing edge of the squeegee stroke. The flux deposit definition improves at higher flux viscosities as can be seen in Figure 6, which shows results of the highest viscosity 250–350 poise flux.

The stencil results also depended on the stencil zone and aperture size. The different zones produced vastly different results. In Figure 6, the left side shows flux deposits for zones 1, 2, and 3 for a 2 mil (50 μm) thick stencil. The right side shows flux deposits for zones 1, 2, and 3 for a 3 mil thick stencil. The best re-

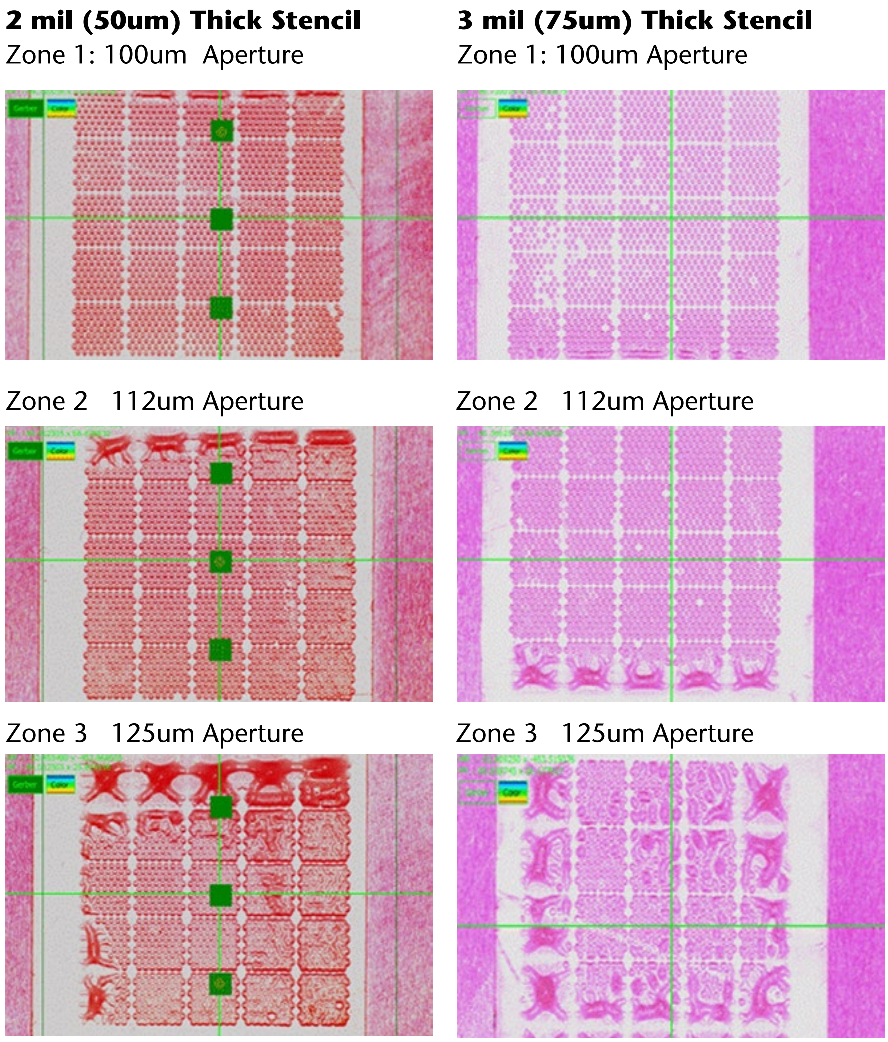


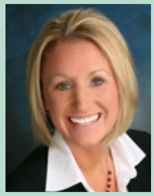
Figure 6: Flux deposits for Zones 1–3, for 2 and 3 mil thick stencils.

sult was produced by the 2 mil thick stencil with apertures of 100 µm square (zone 1). As the aperture size gets larger, 112 µm (zone 2) and 125 µm (zone 3), the flux spreads and shorts between sites. The 3 mil (75 µm) thick stencil exhibits missing flux deposits for both zones 1 and 2 as well as excess flux for zone 3.

Results for the solder paste were very encouraging. Solder brick deposits were made when printing at 25 mm/sec at 2 kgm pressure for a 3 mil (75 µm) thick stencil. The top portion showed solder deposits along the leading edge. The bottom portion showed solder deposits along the trailing edge which resulted from a higher paste deviation near the step edge.

Conclusion

Reservoir flux and solder paste printing can be done in one step with a 3D electroform stencil, but additional studies and techniques need to be explored to achieve the best result. Our study shows that a rubber-pump squeegee blade is necessary for flux to transfer out of the reservoir onto the substrate flip-chip pads. Higher flux viscosities (250–350 poise) gave better flux deposit results. Solder paste reservoir printing of small apertures (100 µm) is possible with type 6 low viscosity (350–400 poise) dispersion solder paste. 100 µm (4 mil) square apertures worked best; 125 µm (5 mil) apertures allowed too much flux and solder paste bridging. We also learned that the test cavity set-up needs to be perfected to avoid the trailing edge of the squeegee blade stroke next to the reservoir wall. **SMT**



Rachel Miller-Short is vice president of sales and marketing at Photo Stencil LLC. To read past columns or to contact the author, click here.

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TOP TEN

News Highlights from SMT007 this Month

1 IPC APEX EXPO 2015 Opens Registration

Changing technologies that are driving the electronics industry will take center stage throughout the IPC APEX EXPO 2015 technical conference and professional development sessions, February 22–26, in San Diego, California. In keeping with the event's theme, "Upgrade Your Tech-NOW-ledgy," the technical conference will feature approximately 100 technical papers detailing original research and innovations from industry experts around the world.

2 Sanmina's India Design Center Earns ISO 13485

The company's India Design Center has been awarded ISO 13485:2003 and EN ISO 13485:2012 certifications for medical product design and development. Achieving these certifications recognizes Sanmina's continuing expansion of its global medical design and manufacturing capabilities. These certifications enhance its ability to provide end-to-end solutions for medical devices in India, a capability very few global EMS companies have achieved.

3 Stone to Lead Primus Technologies as President

Primus Technologies Corporation, a leading EMS provider, announces Stephen Stone has joined the company as president, reporting to CEO Chris Sullivan.

4 Flextronics Joins HMicro's Lab IX Program

Flextronics Lab IX provides a hardware ecosystem that brings together start-ups, OEMs, and technology partners to help disruptive technology companies close the gap from prototype to production. This collaboration will provide HMicro with access to Flextronics' world-class innovative design and engineering support, advanced global manufacturing and supply chain and distribution expertise.

5 Sunburst Now IPC Trusted Source, QML Listed

IPC's Validation Services Program has awarded an IPC J-STD-001 and IPC-A-610 Qualified Manufacturers Listing to Sunburst Electronics. The company met or exceeded the requirements for the electronics industry's most rigorous classification, Class 3, which is intended for high-performance electronics assemblies. As a result, the firm is now listed as an IPC-trusted source capable of manufacturing in accordance with industry best practices.

6 Sanmina Receives Quality Award from Nokia

Sanmina Corporation announces Nokia Networks, the world's specialist in mobile broadband, recently recognized Sanmina for outstanding quality with a 2014 Quality Award for Supplier Excellence.

7 Hunter Technology Secures $8 Million in Financing

Bridge Capital Holding, whose subsidiary is Bridge Bank, has provided Hunter Technology, a leading provider of electronic design and manufacturing services for defense/aerospace, networking/telecom, and medical customers, with $8 million in financing in the form of a line of credit and an equipment guidance line to purchase new manufacturing equipment and support working capital needs.

8 IEC Electronics Reports Revenue of $35.7M in Q4

W. Barry Gilbert, chairman of the Board and CEO, stated, "This quarter's sales results improved on a number of fronts. Our revenue increased compared to the third quarter and we expect solid growth through fiscal 2015. Furthermore, we reduced our debt by more than $5 million and increased our backlog by more than 20%."

9 Cephasonics Selects Piranha as EMS Partner

Piranha EMS Inc. has been chosen by Cephasonics, a technology leader with a game-changing embedded-ultrasound platform, as its EMS partner for the company's newly introduced cQUB-1 (cQuest Ultrasound Box-1).

10 PartnerTech Expands MedTech Business

PartnerTech has signed a new, significant framework agreement with a leading global medical technology company, expanding the cooperation to cover manufacturing and distribution of the company's products globally.

EVENTS

For the IPC's Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar, click here.

For a complete listing, check out *SMT Magazine's* full events calendar here.

2015 European 3D TSV Summit Enabling Smarter Systems
January 19–21, 2015
Grenoble, France

SEMI Arizona Tech Talk: INanoBio
January 23, 2015
Chandler, Arizona, USA

IPC Conference on Assembly and Reliability
January 27, 2015
Ho Chi Minh City, Vietnam

Rocky Mountain Expo & Tech Forum
January 28, 2015
Denver, Colorado, USA

IPC Conference on Assembly and Reliability
January 29, 2015
Bangkok, Thailand

SMTA Pan Pacific 2015
February 2–5, 2015
Kauai, Hawaii, USA

SEMICON Korea 2015
February 4–6, 2015
Seoul, Korea

MEDIX 2015
February 4–6, 2015
Osaka, Japan

LED Korea 2015
February 4–6, 2015
Seoul, Korea

2015 Flex Conference
February 23–26, 2015
Monterey, California, USA

IPC APEX EXPO 2015
February 24–26, 2015
San Diego, California, USA

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