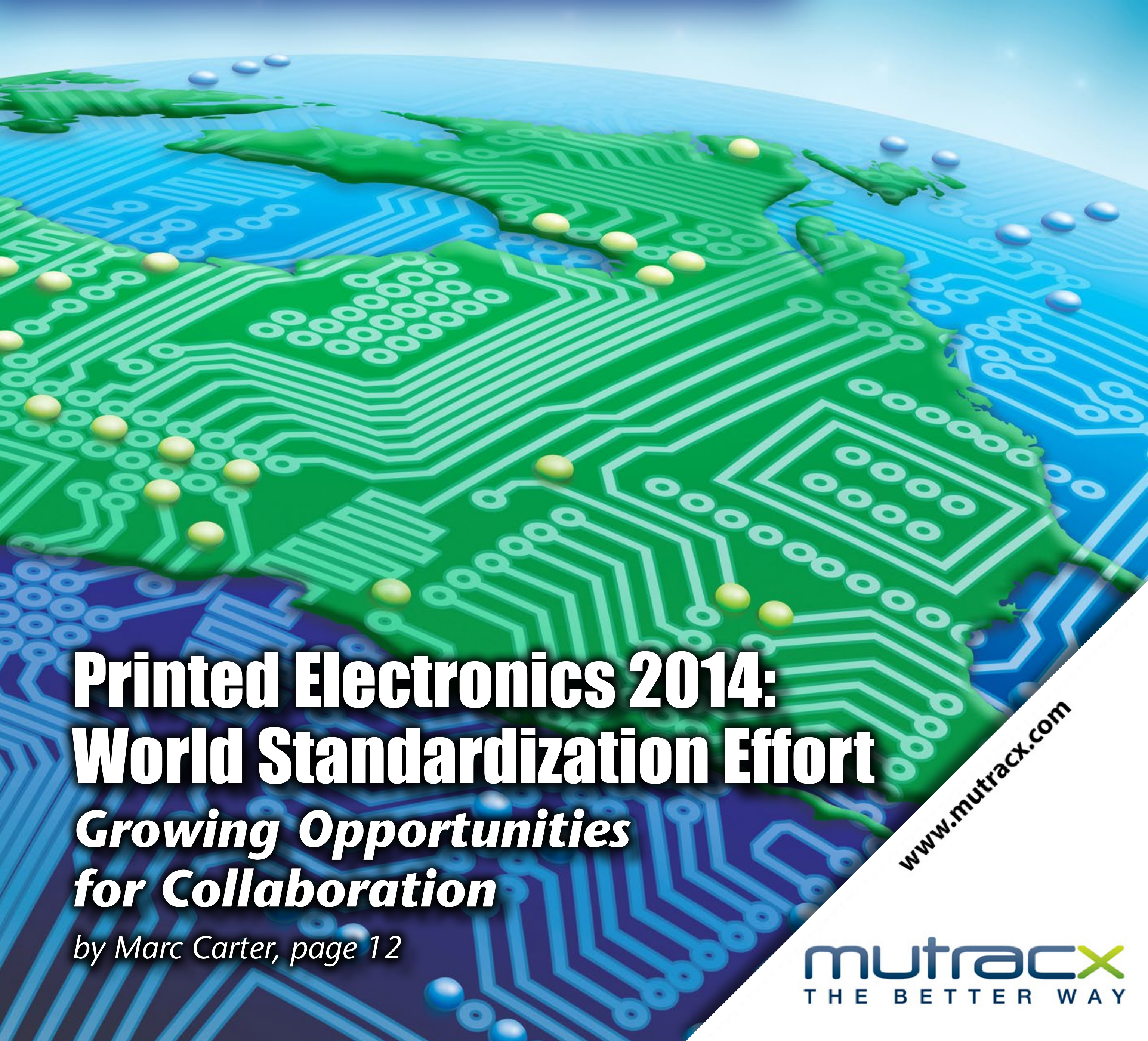
PCB007 PRESENTS

August 2014

the pcb magazine

AN I-CONNECT007 PUBLICATION

PRINTED ELECTRONICS



Printed Electronics 2014: World Standardization Effort

Growing Opportunities for Collaboration

by Marc Carter, page 12

AUGUST FEATURED CONTENT

PCB007 PRESENTS

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Printed Electronics

What is the story with printed electronics? Where have they been and where are they going? Most importantly, how are they being used in today's market? These questions and more are addressed by this month's feature contributors from IPC, OE-A, and more.

FEATURE SHORT

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AUGUST 2014
VOLUME 4
NUMBER 8

THE DEFINITIVE INTERACTIVE MAGAZINE DEDICATED TO THE GLOBAL PCB INDUSTRY

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PRINTED ELECTRONICS

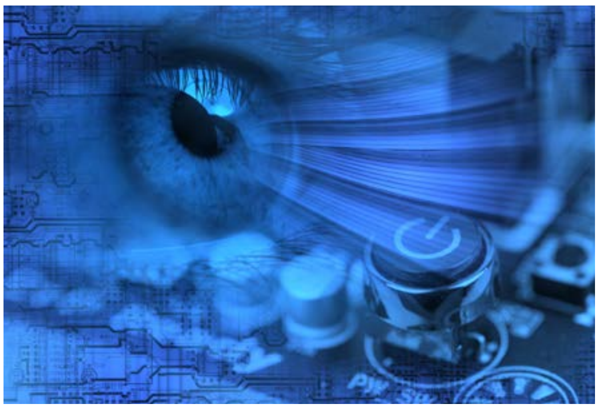
FEATURE COLUMN

Bits and Pieces

by Ray Rasmussen
I-CONNECT007

The PCB Dream

I had a recent discussion with a board fabricator about the expansion of his business. The company was looking into the possibility of buying an existing facility and asked that I keep them informed if I came across any companies that were interested in selling. My first thought was that these guys know how to run a business; they'll do well with a good, strategic acquisition. Then, after thinking about it a bit, I changed my mind. Why buy someone else's obsolete factory with all of its environmental baggage? You might buy a business for a strong customer base or if you were looking for a new capability, but it would have to be really compelling. Instead, build something new.



What if you could put together a new, state-of-the-art, highly automated factory without waste treatment (no air or water)? I have the opportunity to visit such a factory being built right here in the U.S. by an OEM that is making the necessary investments.

Think about it: Increasingly better CAD and CAM software makes going from design to direct imaging more of a reality. If you fully investigated a one-off panel production flow, just in time, along with a system like Mutracx which guarantees panel quality, you could flow from design through etch without a pause. I imagine a PCB factory looking more like a PCB assembly line, with long columns of equipment moving product through the factory. I believe everything is available to take a board from one end to the other in a smooth flow, without too many stops. And if we just invested a bit more in those areas where product stops, we could build a PCB from end to end, quickly and efficiently.

So, if you were starting a PCB facility from scratch, how would you build it? I know that many of you out there can see what's happening and what's possible with the newer systems that are now available. I'd love to see your plan for the PCB factory of the future. Please send me your thoughts. I'll share them with the rest of the readers. Let's see what's doable, today.

Watch for my article this fall that describes a new factory currently taking shape, one that is adopting all of the latest technologies in order to become the PCB factory of the future.

PE, 3D PCB Machine

I've been really intrigued by the marriage of printed electronics and 3D printing. After intently watching the emergence of printed electronics over the last 5–10 years, I can clearly see the intersection between the PCB and PE industries. And now, with the rapid advancement of 3D printing, we're starting to see applications for full-blown PCBs. Considering the cost associated with proving out a PCB design, offering up PCB proto machines seems like the logical first market for these systems. With a market PCB protos alone to be in the billions of dollars, with thousands of potential systems, it must look quite attractive to those building these systems. It's not just the cost of the PCB; it's the value of the time as well. Taking a couple of days or weeks out of the product development cycle is worth a lot more than the PCB. With that in mind, we see the introduction of a few new entries to the market.

Recently, we posted this article on pcb007.com: FirePick Delta 3D: One Step Closer to Desktop Electronics Manufacturing. The system described in the article is quite interesting

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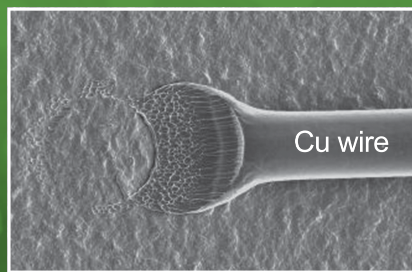
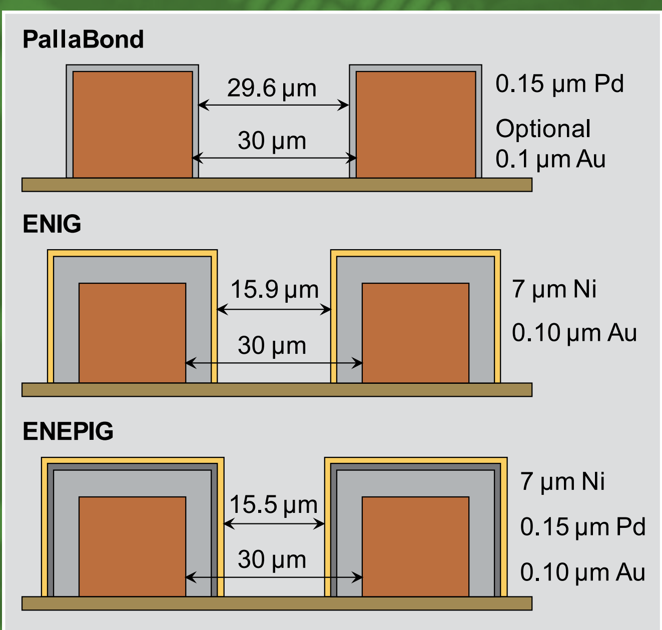


Cu wire 20 µm (Heraeus Maxsoft copper) on pure EP finish view from top

PallaBond – Fine Line Capability



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Recommended Thickness:

	Ni [µm]	Pd [µm]	Au [µm]
PallaBond EP	-	0.15	-
PallaBond EPAG	-	0.1	0.1

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and gives us a glimpse of where this is heading. Here's a quote:

This machine is capable of doing two of the most important and difficult tasks in the process of assembling working electronic devices. While it's not quite to the point of simply being able to press a button and have it print out an entire working device on its own, it certainly shows us how close we are to one day having a machine that will print and assemble working electronic devices at the touch of a button.

In another recently posted article, Advantech Launches Printing Tech for Microelectronic Industry, we find this quote: Features and devices below 5 µm are typically the realm of Chips/VLSI. Features above 30 µm are the realm of traditional printed circuit and device technologies. The manufacturing processes of these two worlds have rarely intersected. Advantech US has developed a printing process that allows these worlds to merge.

I also came across a video, which introduces a system to make desktop PCBs. It's not so much the system, but who is making it: young engineers. Check it out!

It's not doom and gloom here; it's just that there seem to be opportunities emerging in the PCB and assembly space that we all need to be aware of. That's what I'm trying to do. If it were just a few hobbyists making PCBs on their workbench, it would be one thing. Instead, there are two potentially very large industries emerging that are starting to intersect more and more with what we do each year.

For more on the PE, 3D merger, visit our printed electronics news section.

Internet of Things

It's kind of a corny name for something that's about to have an impact on everything we do. If you haven't heard the term Internet of Things (IoT), you will. With a market size in the trillions (yes, with a "t") of dollars, the IoT will touch just about everything we do. We see lots of interest and investments being made by all the major players from just about every industry. And the IoT isn't just for the factory floor, as we found out recently with Apple's announcement that it was moving into the connected home market along with Google and other major OEMs. IEEE jumped into the fray: "The Internet of Things represents a vast landscape of amazing potential; we are just now beginning to grasp how truly far the growing convergence of many traditionally standalone applications and cyber-physical systems can take us," said Oleg Logvinov, IEEE committee chair who is director, special assignments, Industrial and Power Conversion Division, STMicroelectronics.

To read more about IEEE's efforts, click here.

I wouldn't say I'm mesmerized by all these new and emerging technologies and industries, but I am certainly intrigued. I am quite hopeful that our industries will embrace some of the newer manufacturing technologies as well as the emerging ones and incorporate them into their offerings as soon as is applicable. I hope the industry will not be blindsided by what's coming, but will instead seize the opportunities they offer. That's why we cover this the way we do. It's important. Pay attention.

Sustainability in the Supply Chain

Pam Gordon, of Technology Forecasters, has written an article for Green Biz titled How to make electronic trade groups drive sustainability. With help from IPC, Gordon gathered input from association members to gain some perspective on how industry associations engage their members on environmental sustainability. A couple of questions: First, is it their (the association's) job to drive this in the industry? Second, what is "environmental sustainability"? Here's how the U.S. Environmental Protection Agency describes it: *Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.*

Although I think it makes for an interesting article and it caught my attention, I'm not so sure this is an issue for our associations. Where are we falling short? Yes, we all use dangerous chemicals, but what does that have to do with sustainability? If we're doing our environmental bit, what are we doing that isn't sustainable? If we're keeping the air and water clean and recycling everything that can be recycled, why do we need to make this an industry issue? Can we all do our part to lessen our impact on the environment? Sure. But it's the OEMs and the politicians that will drive the effort toward cleaner tech, not the associations.

Sustainability is important to making sure that we continue to have, the water, materials, and resources required to protect human health and our environment. And, if you have a flat roof, which most of our factories do, you should be looking into solar options which will lessen your impact by helping to clean the air and reduce the impact of global warming. I suspect that most, if not all, chemical companies have their own sustainability efforts underway, along with all the component makers. Might be best if, as part of our industry-wide PR efforts, the associations took stock of where we stand today with regard to sustainability. But, I don't think we need associations to drive this.

Well, I hope you are all enjoying your summer. See you soon at the next industry event. **PCB**

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 Passing of an Industry Icon: Dieter Bergman

It is with great sadness that IPC announces the passing of Dieter Bergman, IPC staff member for more than 40 years.

Decorated with countless awards over his lifetime, Bergman's name will forever be synonymous with IPC, and he leaves a legacy of friendships, lasting memories, and what is affectionately treasured by IPC staff and close friends as "Dieter-isms," such as a 45-minute answer to a 10-second question.

Bergman began his career in 1956 as a designer for Philco Ford in Philadelphia, Pennsylvania. He assumed the position of supervisor of the printed circuit design group in 1967, and joined the company's advanced technology group where he specialized in printed circuit computer-aided design. Before that, however, 1962, he became Philco's official representative to IPC and received the IPC President's Award in 1968, the same year he assumed chairmanship of the IPC Design Committee.

Bergman was elected Chairman of the IPC Technical Activities Executive Committee in 1974, and later that year joined the IPC staff as Technical Director. In that role, he was responsible for a number of things: the coordination of standards, specifications and guidelines development; round robin test programs; establishment of workshops and seminars; government and inter-society liaison; and initiating IPC activities in Europe and Asia.

In 1984, Bergman became Director of Technology Transfer to help foster the interchange between design and manufacturing and he continued to serve as a leader in the identification of future technologies and industry needs.

While Bergman had a special place in his heart for the design community, his contributions to the industry as a whole earned him IPC's highest honor, the Hall of Fame Award, in 1985.

Most recently, Bergman chaired the IPC Ambassador Council, a group of IPC Hall of Famers who provide advice and guidance to IPC, and encourage active participation in IPC activities by all of its members to enhance the electronics industry.

"The staff and I feel very fortunate to have known Dieter, and have benefited from his knowledge and his passion for the industry," said IPC President and CEO John Mitchell. "He will be missed, but always remembered as an icon, pioneer and friend."

Printed Electronics 2014: World Standardization Effort

Growing Opportunities for Collaboration

by Marc Carter
IPC—ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

Abstract

Although technically not a new technology, printed electronics is a technology with a growing number of real commercial applications and very broad potential applications. It is the assessment of IPC that printed electronics is at the stage of development where widely accepted international standards, based on consensus by experts from many viewpoints and many countries, could aid global adoption of this technology as an additional tool widely available for the fabrication of electronic apparatus.

At the same time, there are factors that could drive the generation of multiple competing or conflicting printed electronics standards, with unnecessary duplication of effort. Some of the forces behind this possibility (geographical specialization, national interests, poorly developed cooperation between standards bodies, etc.) are discussed. Some means of avoiding this undesirable outcome are suggested.

Current and near-future efforts toward cooperative standardization, technology development, and communication are discussed, as well as a status report on the major efforts in progress. Partnerships that currently exist and partnerships under discussion are presented.

Over the next five years, we envision a number of potential obstacles to both effective and efficient collaborative printed electronics standards development, and to the broader availability of printed electronics as a viable option in electronic fabrication. In this article, we will communicate those areas of concern, and suggest some possible means to avoid them.

We predict the general success of printed electronics, if success is defined as the wide availability and acceptance of printed electronics technology as one of many possible tools


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which may be employed in electronic fabrication, when it is the most appropriate solution to a particular problem.

Historical Background: How We Got Here

As is typical with any major technological shift, when alternatives to wired circuits were needed, several possible paths were identified, but no one could predict with certainty which paths would succeed in the marketplace. The path (or paths) chosen depend on the technologies and support for each available at the time, the various market, environmental, and societal forces in play at the moment, and a bundle of additional imponderable factors usually lumped together under the heading of "luck."

As an illustration, consider the introduction of the automobile. Early examples of successful automobiles were powered by spark-ignition engines with various fuels, compression-ignition engines (i.e., diesel), battery-electric motors, and steam. Each had sufficient advantages and disadvantages, and the situation was sufficiently complex when viewed from the perspective of the times, that the winners were not easily predicted. Eventually (due to a complex combination of events, materials available at the time, and market forces) internal combustion (Otto cycle ignition engines, and compression ignition) powered vehicles became the dominant types.

Similarly, when the world needed products that were more complex, or more miniaturized than could easily or economically be produced by traditional hand wiring techniques, several plausible alternatives emerged, including deposition of conductive materials on an insulating substrate by printing or other techniques, auto-

First production printed circuits were "Printed Electronics"

The first mass production of complete printed circuits as they are known today, was set up at the plant of Globe-Union, Incorporated, at Milwaukee, Wis., and a subsidiary plant at Lowell, Mass. Facilities were provided for daily production of over 5,000 printed electronic subassemblies for the mortar fuze shown in figure 1. The plate, on which a complex electronic circuit was printed was made of thin steatite 1¾ in. long and 1¼ in. wide. The circuit was produced by the stencilled-screen process [1] pioneered by the Centralab Division of Globe-Union. Figure 2 shows a two-stage amplifier printed on a thin, ceramic plate alongside a similar amplifier constructed according to present day standard production methods. The reverse sides of the units are seen in figure 3.

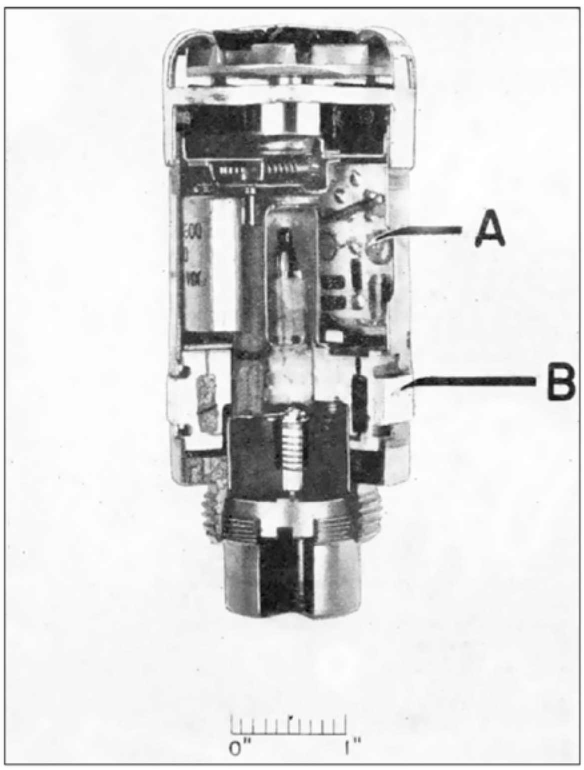

FIGURE 1. *Cutaway model of a simulated radio proximity fuze for mortar shell showing an electronic control circuit on steatite block B, and the remainder of the circuit painted on steatic plate A.*

Figure 1: From "Printed Circuit Techniques" by Cledo Brunetti and Roger W. Curtis (National Bureau of Standards Circular 468 first issued 15 November 1947).

mated wire "stitching" (one well-known trade name is "Multiwire") and variations on the subtractive techniques.

The simplest, and to some, the most obvious early solution involved depositing a conductive material where it was needed: to connect the elements of a circuit into some useful assembly. The various alternative methods of depositing conductive materials on an insulator eventually yielded what is believed to be the first high-volume production examples of printed circuits during World War II.

An alternative method generally credited to Paul Eisler involved depositing a chemically resistant ink (resist) on a copper-foil-clad insulating sheet in a pattern that would eventually connect component parts as wires would have in the past. Thus prepared, the sheet was immersed in a solution that dissolves copper etchant, leaving the protected copper in place. The resist could then be removed with solvent, component leads inserted in holes drilled "in board" and then soldered to the copper conductors.

1950–2000: Printed Electronics—the Path not Taken

Improvements in the placement of the resist, methods developed to electrically connect electrical conductors on stacks of layered circuits (multilayers), meant that printed electronics (i.e., depositing an electrically conductive paste on an insulating substrate) could not economically meet the speed, miniaturized features, and precise size and positioning required in the rapidly developing electronics industry, given the technologies of the day.

Thus, for the second half of the 20th century, printed electronics was a minor player in the

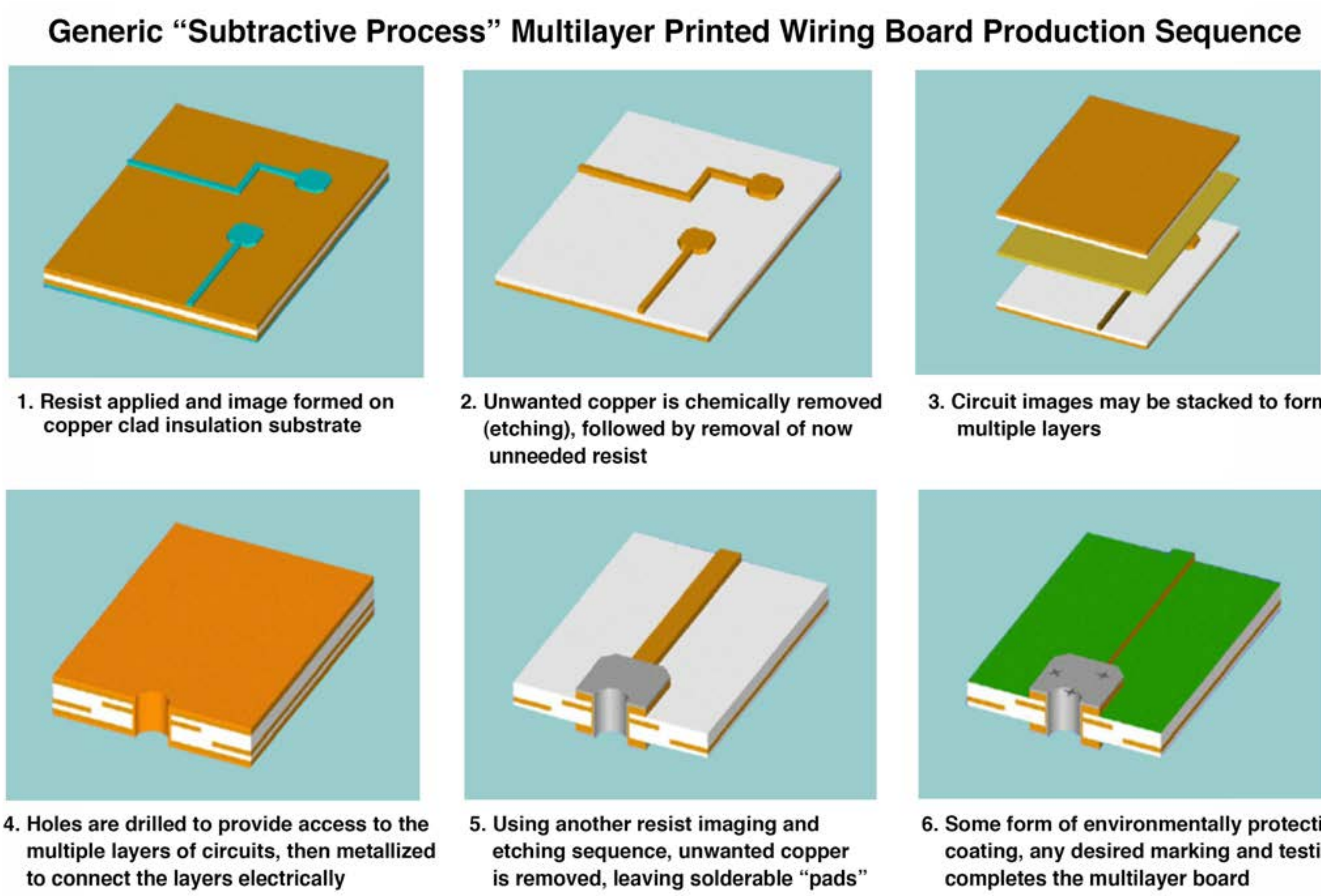

Figure 2: Subtractive process multilayer printed wiring board production sequence.

electronics industry. The subtractive process of etching away most of the copper, with all of its chemical requirements and waste generated, was the path we followed. Evolutionary improvements reduced feature size and improved precision of feature location, facilitating the miniaturization that was (and to some extent, still is) the driving force behind electronic product improvements.

As the century waned, a combination of cost pressures, environmental concerns and expansion of electronics applications previously unimagined started to run into areas where the subtractive approach reached limitations. Very large displays with thousands of identical thin film transistors (TFTs), e-readers, new directions in lighting, photovoltaic interest, and very low-cost electronic applications on renewable (sometimes disposable) substrates renewed interest in the potential advantages inherent in placing functional materials only where needed.

Simultaneously, material science provided new options for functional electronic materials that began to address limitations the inks and substrates of earlier generations. Advances in nanomaterials, semi-conductor materials, and substrates accompanied the start of a number of new ventures, each encouraged by optimistic projections of dot-com-like growth, and the looming prospect of obsolescence of all existing forms of electronic production. While there were isolated examples of commercial success using the technology where and when appropriate, the next decade was a lesson in industrial/technology reality.

2000–2010: Too Many Promises, Too Little Commercialization

Inflated growth projections, the lack of widespread infrastructure, lack of universally acceptable criteria (for acceptance, reliability, testing, etc.) and improvements in the well-established existing alternatives limited the growth of the market. A number of major companies invested heavily on the promises and drove important developments in the technology and materials, but without the "killer app" success they anticipated. The situation is in some ways analogous to the automotive industry in the first 20 years of the 20th century, where 1,300–1,400 automobile manufacturers formed in the U.S., most of which had disappeared by 1920.

The legacy of this period remains a barrier to investment and consideration of printed electronic alternatives among main-stream electronic manufacturers. In the latter part of the decade, successes of more realistic, "hybridized" (i.e., where selective application of printed electronic technology in an otherwise conventional electronic fabrication sequence) applications have begun to erode the skepticism. Continued steady growth in what became known as traditional printed electronics (membrane switches, electroluminescent [EL] applications, auto rear-window defoggers, etc. Ninety-five percent of which was screen printed) continued through the decade also helped overcome some reservations.

2010: A New Beginning

In 2010, IPC membership tasked IPC staff with a realistic assessment of printed electronics, including:

- 2010: Problem Assessment: Existing vs. Desired State of Industry
- Assessment of 2010 Issues Impeding Market Development
- What was Needed to Achieve Desired State
- Select & Prioritize Needs based on 1) Achievability 2) Resources

A breakdown of these four areas follows.

2010: Problem Assessment

Situation Analysis:

In 2010, our assessment of the existing general state of the printed electronics industry worldwide determined that there were isolated examples of commercial success (blood glucose monitor strips, some RFID, some membrane switch applications, etc.). They each shared certain characteristics, namely:

- Each was a strictly bilateral arrangement (one customer and one supplier), with unique and privately agreed design criteria, acceptance and performance requirements and (generally) building approaches

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- Each success was developed in isolation and any parallel efforts elsewhere must therefore be uniquely re-developed
- Technical solutions to any problems encountered were similarly re-developed for each case

All of these made for an inefficient repetition of effort for each project. In addition, there was no general agreement on definitions, expectations, etc.

2010 Issues Impeding Market Development

We identified a number of impediments to a fully functional global printed electronics marketplace, including (but not limited to):

1. Additional research and development to refine, expand, and fully characterize existing successful material and process sets was needed.
2. Basic research to identify new materials and processes to address cost, reliability, environmental, health, and safety issues associated with some of the existing material and processes was distributed (piecemeal) among many centers around the world.
3. Process developments were needed, particularly linkage of existing unit operations into integrated production sequences, as much of the equipment available had been developed and optimized to perform one kind of process step only.
4. Market projections (both in size and direction) tended to be highly speculative, in part because the concept of a "printed electronics product" was poorly defined, with very indistinct boundaries.
5. No world-wide system existed whereby a potential buyer could describe to multiple potential suppliers what was desired in terms of a printed electronic product in a consistently understood manner in either performance, reliability, acceptance requirements, etc.
6. While there were multiple venues where technological developments, basic research, market potential were discussed, there were too few forums where existing success stories (and the failures along the way) were presented to other would-be practitioners of the art as "lessons learned" opportunities.
7. Printed electronics incorporates elements of both traditional electronics manufacture and traditional printing technologies. Even skilled designers in one of the traditional fields might be unaware of design considerations critical to success in the other.

The first three of these impediments were and are beyond IPC's scope. The fourth might be achievable by IPC, but was deemed less efficient than development of a partnership to address the issues by expanding the scope of an existing platform. The final three we judged as well within our established abilities. With those caveats, we concluded that sufficient maturity in the individual elements necessary had been achieved to allow the development of a true global industry, with cooperative support from IPC and many others.

Our working assumption was that in order to achieve the desired state of the industry, it was necessary to reduce or eliminate the wasted effort in repeated "re-inventions of the wheel." In part, mutually understandable means of communicating methods, needs and requirements were necessary. IPC has been in the business of facilitating global, consensus-based standards, test methods, and guidelines in the traditional electronics industries for more than 50 years. That body of work serves as the means of communication described earlier for the traditional electronics industry, so it should be possible to build the equivalent communications tool for printed electronics, with the right participants. The same could be said of the design requirements.

IPC has a long history of providing technology forums for lessons learned in the traditional electronics manufacturing arena and has well established methods to support such events. What was lacking (at least at the time) was sufficient specific technical background to insure that any such event would be truly useful to attendees. This was another opportunity to couple our resources with those of other organizations with the specific knowledge to support the growth of this industry for the benefit of our existing and future member companies. Organizations with whom IPC has partnered to a greater or lesser degree are shown in Figure 3.

Our conclusion on completing that assessment, including likelihood of success and resources available can be summarized as:

Maximum benefit from IPC resources will be achieved by:

• Global consensus-based printed electronics standards

• Design guidelines (eventually standards) to bridge the gap between traditional electronic design requirements and the traditional print technologies

• Fact-based market data for decision makers (developed in partnership with others)

To consolidate IPC's parallel efforts in support of these targets in one framework, IPC formally established the *IPC Printed Electronics Initiative* in early 2012.

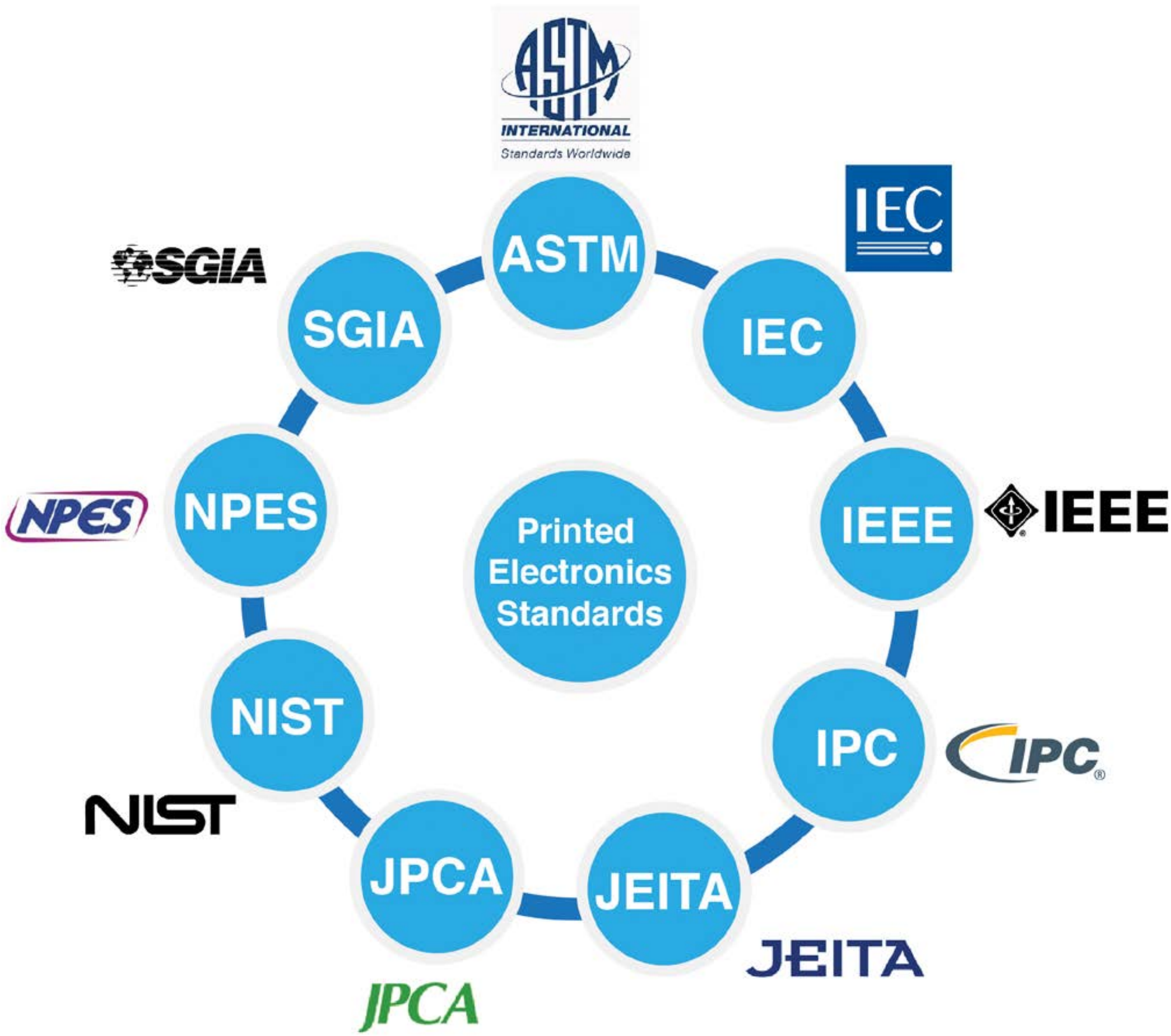


Figure 3: Partial list of organizations that have partnered with IPC.

IPC Printed Electronics Initiative: Overview

IPC has learned a thing or two in its more than 50-year history in supporting rapid technology-to-production transitions, so we set out some guiding principles for this effort. The first is a strong emphasis on collaborative partnerships with groups and organizations that share common high-level goals. In today's lean operating environment in technical organizations, and in a fast-developing field like printed electronics (or large area electronics, or flex-hybrid electronics, or any of the other near-synonyms used to describe this field), the industry can ill-afford duplication of effort. With the goal of supporting the development of a truly global marketplace, one of the most destructive possibilities is having multiple international, regional, or national groups generating "not-quite-duplicate" or even conflicting documentation to interfere with smooth and efficient exchange of ideas and requirements.

We have been fortunate in our collaborative efforts and succeeded in releasing the first three operational-level documents (two standards and one design guideline), with help from many international partners, but especially close cooperation with JPCA-Japan Electronics Packaging and Circuits Association. The current standards development landscape is shown in Figure 4.

There are at least three items of interest we would like to highlight in this graphic:

- First and foremost, in keeping with our goal of fostering collaboration and avoiding overlapping efforts, all three of the documents published to date are "dual-logo" publications, jointly created and managed by IPC and JPCA
- Second, even as the first publications were being released, rapid developments in the printed electronics field made it obvious that revision and expansion of those documents, and additional documents covering other aspects of the technology and marketplace would be needed immediately
- Third, with people from many organizations and many nations working on subcommittees D61 through D66 (with more to follow), the "master" D60 committee had to take an active role in prioritizing efforts, redistributing resources, and maintaining close communication between the subcommittees. This steering committee has had good success to date, and will serve this effort, and the industry, well into the future.

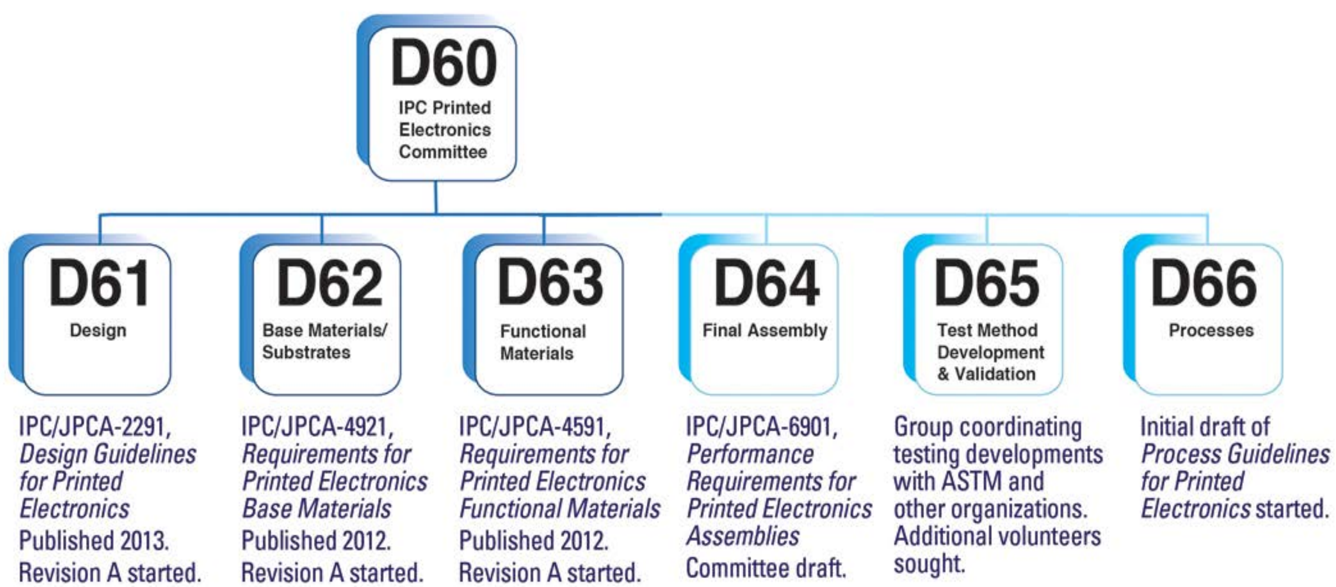
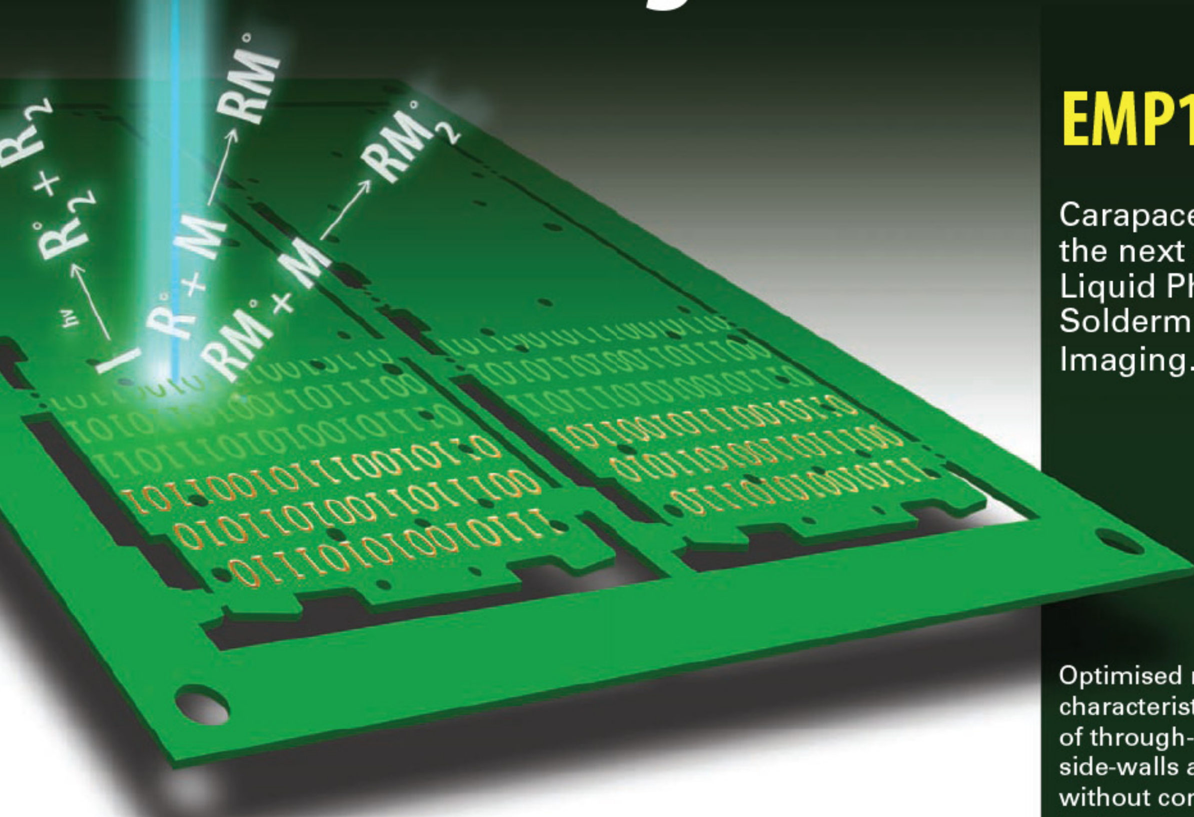


Figure 4: Summary of the current standards development landscape.

Direct Image Solder Mask



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Other current collaborative activities in progress include:

- FlexTech Alliance:
  - Planning stages of summit on Global PE Standards priorities
- OE-A:
  - Exploring alliance options; joint PE-Roadmap discussion
- IEC TC119-Participant/member.
  - "D" Liaison status to materials group for IPC pending
  - "Normative reference" status is goal for already-published IPC/JPCA standards
  - Working model: Use IPC lead and faster pace to guide content of international, and IEC global and governmental status to maintain global coordination
  - ASTM-D-65 test methods
  - Co-meeting with ASTM F01.18 at APEX2014; close contact maintenance

As a side note, the spirit of collaboration and cooperation in this growing industry is not limited to IPC. The IEC TC119 committee was in the early stages of developing requirements for barrier layer materials, a critical element of many printed electronics applications. They discovered that the IEEE was working on similar requirements and IEC TC119 has thrown its support behind the IEEE effort.

With all the positive collaborative efforts underway, there are still challenges to overcome.

Global PE Standardization: Challenges Ahead

As noted earlier in this article, throughout (roughly) the first decade of this century, there were promoters of the printed electronics concept whose excitement at the possibilities led to underestimating the effort and time required to achieve success, and overestimating the growth in applications and profits. There were well-known corporations who invested heavily and lost heavily based on those predictions. Living down those excesses of the past, and demonstrating value in rational, appropriate applications of this technology is an ongoing communication and education effort of the IPC Printed Electronics Initiative to encourage further prudent resourcing of printed electronics development.

Another potential challenge is actually a side-effect of the breadth of possible applications of the loosely-defined printed electronics technology. Building on national and regional strengths leads naturally to a degree of segmentation of printed electronics technology application types by region. Examples include (and these are oversimplified):

- North America=Medical
- Germany=Auto
- Korea=Display and portable
- Japan=Hybridized conventional/PE combo/components

The risk, of course, is that this regional specialization will lead to not-quite-parallel regional or national development of standards particular to each end application, which doesn't match the versatility of the underlying technology. There is a political element to this challenge in cases where a national government, for reasons of industrial policy, may seek to dominate a particular aspect of a technology and encourage this regional compartmentalization. If unchecked, this leads to (and we know this from similar experiences in conventional electronics) a deferred burden of time and duplication of effort as the globalization of the industry drives de-confliction of these documents. It is better to coordinate from the beginning.

The final challenge we'll discuss (though many more exist, it is beyond our scope here) is in the natural and healthy desire of the initial innovators in this (or any other new) technology to preserve their lead market position by keeping as much of the technology and methods development as proprietary. There is always a balance to be maintained between protecting the market advantage hard-won technology developments can bring (maintaining or growing the size of your slice of the pie) and the market advantage that growing the industry can bring (baking a bigger pie). The trick lies in sharing enough developed technology so that the market (and your customer awareness, supplier breadth of offerings) grows to your advantage,

while maintaining as much of your lead position as practical.

In the end, the technical solution will either become known or alternatives will be developed, which may negate market leadership. In order for the true global marketplace to grow to its full potential, there needs to be sufficient sharing of information to provide common bases for the consensus-based standards (and we have already concluded that the existence of standards is one necessary condition for facilitating global market growth).

Conclusions

- Cooperatively developed, consensus-based standards are one, necessary, but not sufficient requirement for global printed electronic developments. Many other technical, political, logistical, etc. issues must also be addressed
- Competing standards development efforts will harm the industry; means to combine, or at least coordinate content are the goal
- A more collaborative approach will advance printed electronics to achieve full potential **PCB**

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Marc Carter is the director of Technology Transfer at IPC. He is responsible for oversight of IPC technology and printed electronics roadmap activities, and supporting IPC efforts in regulatory compliance, training, and support of the developing printed electronics industry. Carter has been actively employed in electronic fabrication, assembly, and applied material science industries for approximately 36 years and joined IPC in 2011.

Cheap, Flexible Printed Cameras from Graphene

Dr. Felice Torrisi, university lecturer in graphene technology, has been awarded a Young International Researchers' Fellowship from the National Science Foundation of China to study how graphene and two-dimensional materials could enable printed and flexible eyes.

The vision is to create a technology for cheap, flexible cameras that can be printed or stamped on plastic or paper. "It might eventually be possible to embed these printed, flexible optoelectronic devices into clothes, packaging, wall papers, posters, touch screens or even buildings. Everybody with a printer at home will be able to print their own "artificial eye" and physically stick it to a flexible mobile phone," Felice said.

The goal of the 18-month project is to design, develop and characterize inkjet printed 2D crystal-based flexible photodetectors and study their integration with commercial electronics.

"Photodetectors are needed in cameras, automotive applications, sensing and telecommunications, medical devices and security. If these were flexible they could be integrated in clothes, rolled up or printed over any irregular surface, substantially increasing the quality of printed and flexible electronics."

Hybrid Systems for Organic & Printed Electronics

Photo courtesy Thin Film Electronics ASA

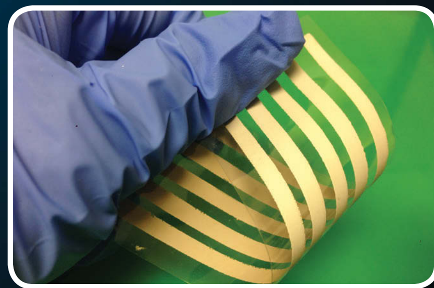
by Klaus Hecker
ORGANIC AND PRINTED ELECTRONICS ASSOCIATION (OE-A)

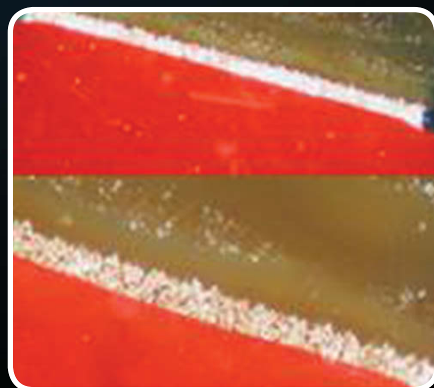
The organic and printed electronics industry is on the upswing. That is what the first OE-A Business Climate Survey shows. One central point that helps the industry to grow and develop is hybrid systems, as identified by the latest edition of the OE-A Roadmap. Hybrid systems combine classical silicon and printed electronics components. That opens up new possibilities for the PCB industry.

Participants expect a 16% increase in sales turnover compared to the previous year. This trend is going to continue through the upcoming year 2015—along the entire value chain of the printed electronics industry, from material suppliers to end users, as well as in all global regions: Europe, Asia and America.

The OE-A's first Business Climate Survey shows that the young industry has developed into its own sector with a bright future. Thin, lightweight and flexible are characteristics of organic and printed electronics. These features enable new applications in numerous areas, with particular focus on consumer electronics, automotive, lighting, packaging and printing, pharmaceuticals and energy. In many of these fields hybrid systems already enable market entry and new applications.

Hybrid systems are one of the key trends that the fifth edition of the OE-A Roadmap has





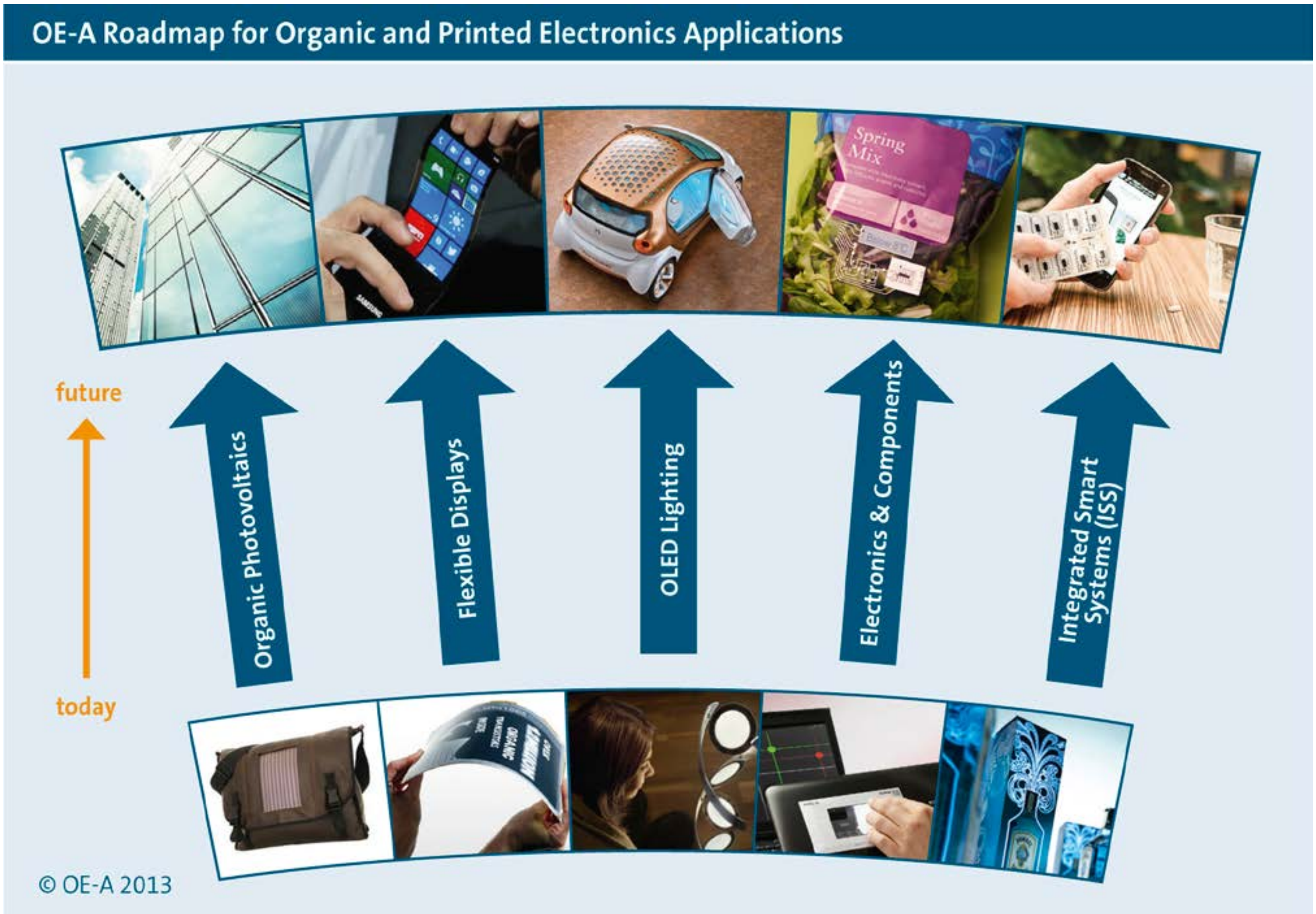


Figure 1: OE-A Roadmap illustrating the common perspectives of OE-A members. (Source: OE-A)

identified for the organic and printed electronics industry. The roadmap represents the common perspectives of the OE-A membership—with more than 250 experts who worked together on it. Based on the analysis of all applications and technologies, key challenges ("red brick walls") that have yet to be overcome and key trends to get organic electronics ready for mass production were identified.

"In the future, organic and conventional electronics will be combined more and more," OE-A Chairman Dr. Stephan Kirchmeyer says. "Hybrid electronics—combining printed, flexible electronics with building blocks containing classical (silicon) electronics—will pave the way for mass production. The industry is working towards integration of organic and printed electronics in new products, and this opens up new possibilities in the market."

As the OE-A Roadmap has identified, hybrid systems that integrate printed and silicon-based components in a heterogeneous process will lead to new products and be especially important for market entry in the short and medium term. In addition, production techniques well known from PCB manufacturing can be employed. For these hybrid technologies, the roadmap summarizes combinations of processes including large-area photolithography, screen printing or printed circuit board technologies that make use of flexible substrates (e.g., polymer films or paper). Materials are deposited by spin coating, doctor blading or large-area vacuum deposition, and in some cases, also partially by printing. Ink-jet printing and laser-patterning are additional techniques that are grouped in the hybrids and enable production at mid-range cost levels.

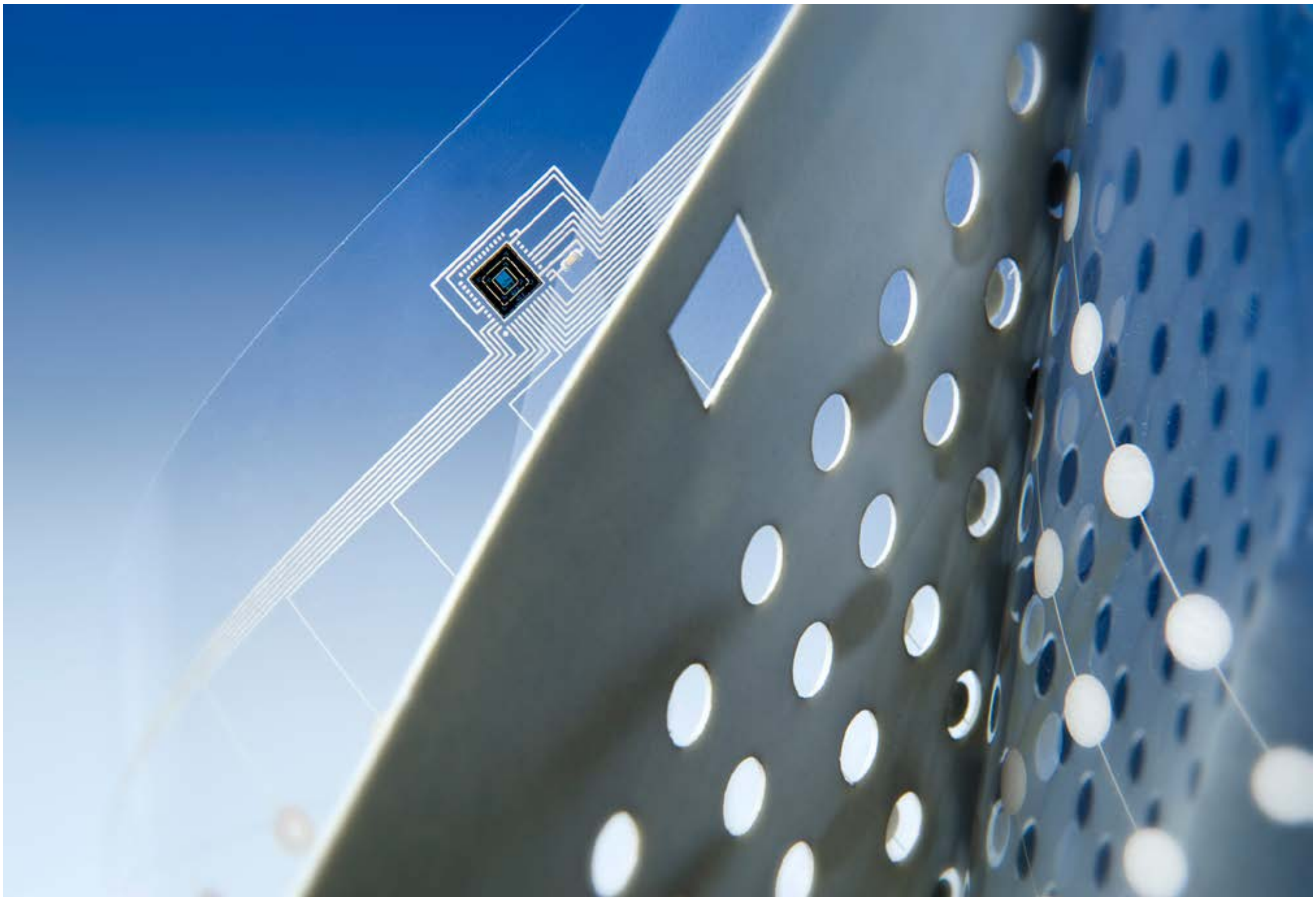


Figure 2: Example of a hybrid system: printed pressure sensors on flexible substrates combined with Si chip. (Source: Holst Centre)

Numerous Products Already Available

Numerous products including hybrid systems are already on the market in large numbers: Printed sensors, which when combined with silicon electronics, can measure temperature or glucose; touch screens and surfaces that consist of a printed capacitive sensor array and silicon electronics; hybrid systems that may improve smart packaging. One example is an illuminated cardboard box package that combines printed electroluminescence with a silicon driver chip. Other examples include: RFID tags with printed antennae and Si chips; seat recognition for

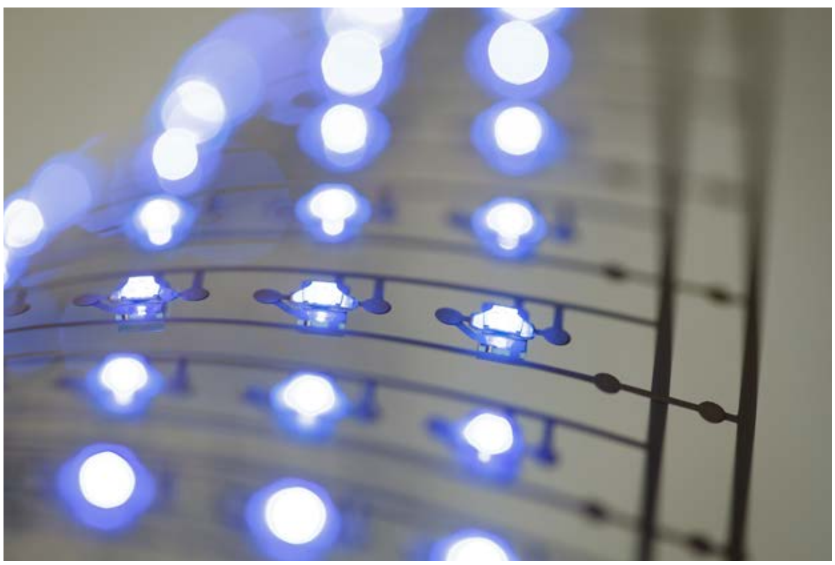


Figure 3: As seen in this lighting foil, hybrid systems bring together classical silicon and printed electronics components. (Source: Holst Centre)

Figure 4: This hybrid smart blister pack and an additional smartphone app support patients in taking their medicine. (Source: Holst Centre)

automotive applications with printed pressure sensors on flexible substrates and Si chip; smart textiles combining printed conductive paths on garments with Si sensors and electronics.

New Production and Assembly Technologies Needed

Hybrid applications afford special demands on the assembly technique. To assemble the chip and connect it to a flexible substrate in a confined space, special know-how and high precision are required. Today, several components such as sensors or displays are printed onto different substrates in a first step. In a second step, they are assembled and interconnected on a flexible circuit board. In the future, more and more components will be printed directly on one flexible substrate in subsequent production steps. Since the substrate is flexible, the interconnections need to withstand more extreme conditions than those found on rigid boards. New high-throughput assembly and interconnection technologies are under development.

The OE-A is supporting and fostering the trend towards hybrid systems by setting up a working group dedicated specifically to this topic. OE-A members along the whole supply chain—from material suppliers to end-users—are working together to provide an overview on available technologies and applications. The group is also identifying gaps in the process chain. By staying in close contact with end users, the working group is developing concepts to overcome these hurdles. **PCB**

About OE-A:

The OE-A (Organic and Printed Electronics Association) was founded in December 2004 and is the leading international industry association for organic and printed electronics. Members are world-class global companies and institutions, ranging from R&D institutes, component and material suppliers to producers and end users. More than 220 companies from Europe, North America, Asia and Australia are working together to promote the establishment of a competitive production infrastructure for organic and printed electronics. The vision of the OE-A is to build a bridge between science, technology and application. The OE-A is a working group within the German Engineering Federation (VDMA). For more information, visit: www.oe-a.org, www.lopec.com.

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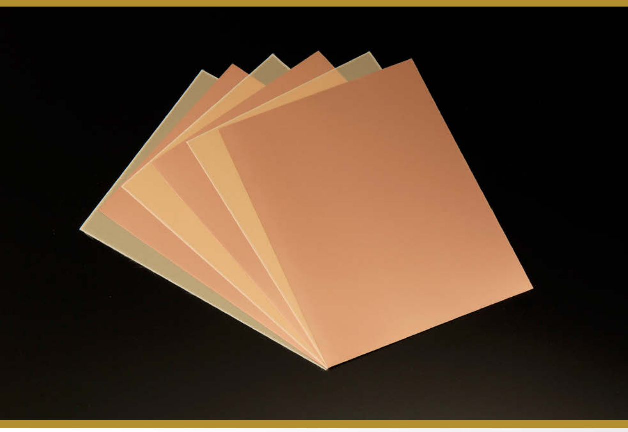

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Piezoelectric, Pyroelectric, and Ferroelectric Materials for Printed Electronics

by Josh Goldberg
TAIYO AMERICA INC.

Introduction

For a while now, the term “printed electronics” has been used freely, though many people don’t have the full picture of what this industry is all about. Printed electronics (PE) is a platform for bringing down the production costs of electronic devices so that they can be incorporated or sold to the item level (e.g., cereal boxes, battery packs, POP displays, etc.). Incorporating devices such as electroluminescent displays can help grab consumers’ attention. Integrating an RFID tag into a box can inform a consumer about the product’s ingredients, vitamin content, and upcoming offers related to that particular product.. Having said that, all of the electronics that are incorporated into a product have to be inexpensive enough that the packaging, along with the electronics, can be disposed of after the product is used.

Several factors can drive down the cost of these devices, such as the use of inexpensive substrates. Such surfaces as PET, PEN, paper, and textiles are all relatively inexpensive and lend well to the next factor that can drive cost down, and that is the printing process.

One of the main cost-saving goals for PE is to move towards a fully additive printing process. What this means is that the material is only printed in the places where it is functional. There is no masking process where material is removed after such steps as etching. This produces a cost savings in not just the labor and material aspect, but it also allows for the device to be manufactured with roll-to-roll processes. The rapid production rates enabled by this process allow for a potentially large cost savings in manufacturing, as well as being able to utilize the flexible nature of the inexpensive substrates.

Another way to save on production costs is to use well established materials in novel ways. Some polymeric materials have been used for decades for products such as battery covers, paint additives, and insulated foams and sealants. By investigating these materials' properties, we find that some of them have uses outside of their intended function. Piezoelectric, pyroelectric, and ferroelectric materials have been around for quite a long time, but are continuing to find useful niches in emerging electronics markets.

Piezoelectric Materials

To understand how a piezoelectric material functions, a general understanding of the piezoelectric effect is needed. The piezoelectric effect is the relationship between mechanical stress and electrical voltage. As stress is applied to a material (usually, but not always, through compression), electrons are bumped off the molecular structure, thus generating an electrical current. The reverse of this process is also true. As electrical current is introduced to the molecule, it causes the solid in most cases to expand.

The piezoelectric effect was first demonstrated through experiments by Jacques and Pierre Curie in 1880 based on some initial work by Rene Just Hauy and Antoine Cesar Becquerel. The Curie experiments noted the piezoelectricity with materials such as quartz and rochelle salt (sodium potassium tatrate tetrahydrate). The next year, Gabriel Lippmann mathematically deduced that the reverse piezoelectric effect should also be true. Experimentally, this was then proven by the Curies. Over the next couple of decades, materials exhibiting piezoelectric effect were characterized but not utilized in any practical applications. In 1910, Woldemar Voigt published the "Textbook on Crystal Physics," which describes that 20 out of 32 naturally occurring classes of crystals have the proper symmetry to exhibit piezoelectricity.

"PVDF is important to the printed electronics world in that it is a polymeric material that can be incorporated into solvent-based systems and made into an ink, making it particularly useful in inkjet formulations."

The first practical use for piezoelectric materials came in WWI. Paul Langevin, a French scientist and student of Pierre Curie, developed an ultrasonic submarine detector, known today as sonar. The success of sonar led to other developments using piezoelectric materials. Ultrasonic devices helped to dramatically further materials research with more accurate instruments to measure the viscosity and elasticity of liquids. Better solid characterization led to safer building materials, because cracks and air bubbles were easier to find.

During WWII, several countries independently researched piezoelectric materials, leading them to develop synthetic materials such as PZT (lead zirconate titanate), a major piezoelectric material still used today. After the war, due to restrictive patent laws and lack of informational sharing in the United States, piezoelectric materials research stalled. However, Japan, not suffering such restrictions, picked up materials research and took the forefront of the device research for a number of years. This lead to the development of a number of piezoelectric devices including igniters used in gas grills and some of the first television remote controls.

In 1969, the synthetic polymer polyvinylidene fluoride (PVDF) was discovered to have very strong piezoelectric properties, as well as pyroelectric and ferroelectric properties. This material is commonly found in additives for paints, electrical wiring insulation, aerospace materials, chemical bottle liners, headphones, and batteries. PVDF is one of the few materials that exhibit the reverse piezoelectric property. In other words, it compresses in volume when an electrical field is applied to the material. PVDF is important to the printed electronics world in that it is a polymeric material that can be incorporated into solvent-based systems and made into an ink, making it particularly useful in inkjet formulations.

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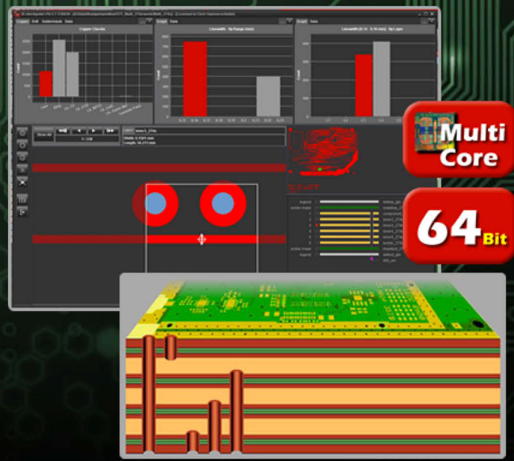

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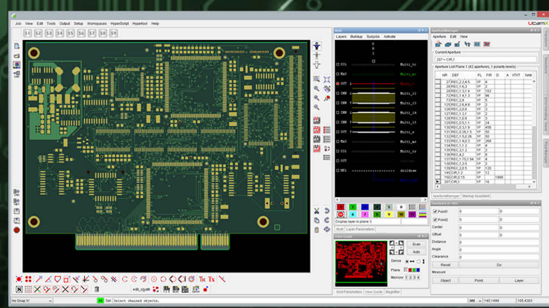

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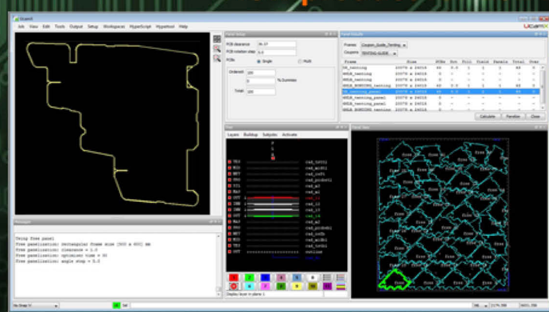

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Typically, you would see piezoelectric materials in items like printed sensors (particularly, vibrational sensors). Perhaps the most common use of piezoelectric materials is found in inkjet printers themselves. By sending an electric signal to a piezoelectric crystal located in the print heads, the crystal expansion creates a pressure wave that forces inks through the orifice of the inkjet printing heads. So while piezoelectric materials can be printed for various devices, perhaps the most important use of these materials is for the printing platform itself.

Pyroelectric Materials

Pyroelectric materials are a subset of piezoelectric materials. In other words, if a material is pyroelectric, then it is also piezoelectric, but not necessarily the other way around. Out of the 20 naturally occurring crystal classes, 10 also exhibit pyroelectric properties. Pyroelectric materials generate a temporary voltage when the material is heated or cooled. This is not to be confused with thermoelectric materials, which exhibit a permanent voltage change when subjected to temperature change. One way to visualize the relationship of piezoelectric materials and pyroelectric materials is in the diagram below

Pyroelectric materials were first noted in 314 B.C. by the Greek philosopher Theophrastus. While he was more of a botanist and ecologist, as witnessed by the books that he wrote, he was the first one to note that the stone "lyngourion" (most likely tourmaline) became charged when heated. This charged crystal then had the ability to attract bits of straw and wood while other heated rocks did not have any such attraction. In 1707, Johann Georg Schmidt studied tourmaline and noted that it was not attracted to cold ashes, but only the hot ones. Further studies in 1747 lead to tourmaline being called lapidem electricum, or the "electric stone." Interest in the electric properties of some crystals in relation to temperature change led the Curie broth-

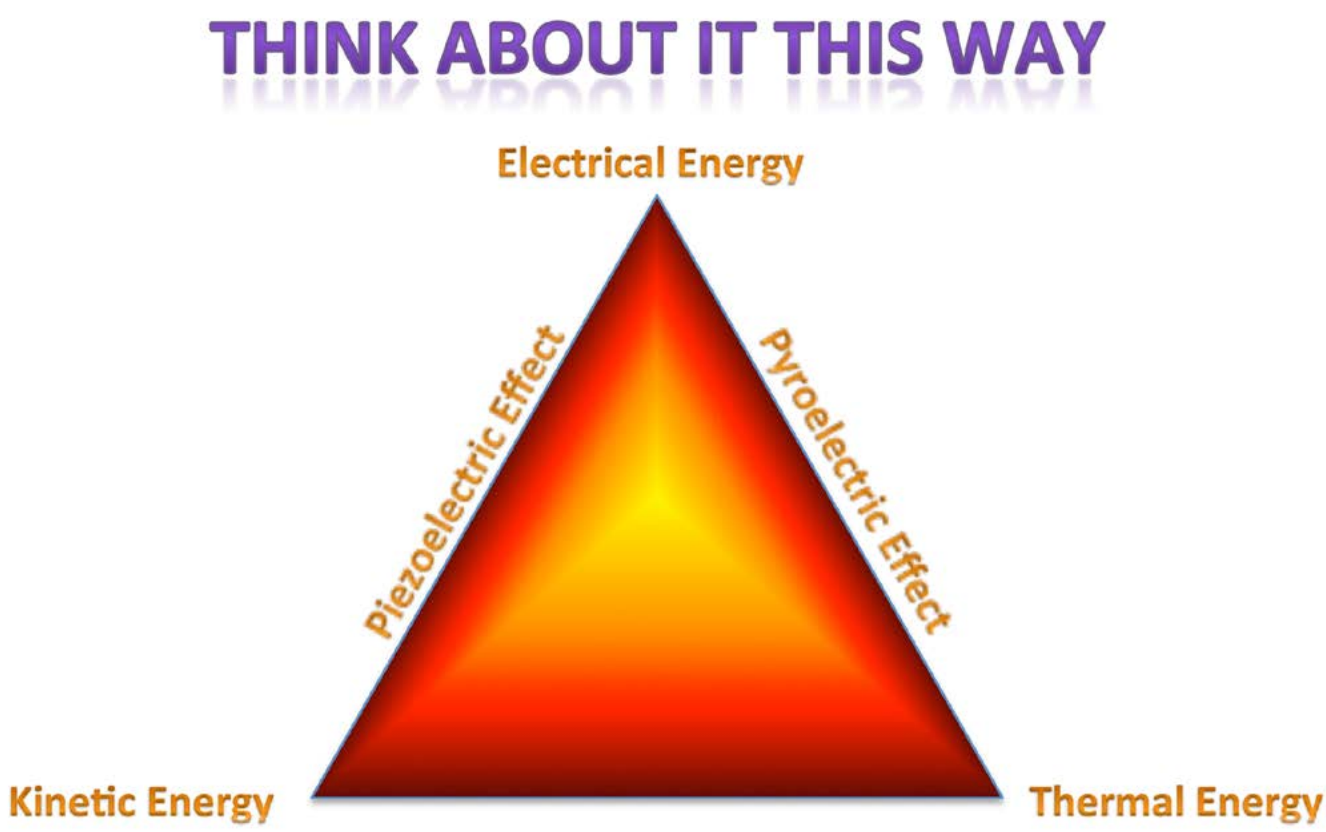

Figure 1: The relationship of piezoelectric materials and pyroelectric materials.

ers to start investigating this group of materials, leading to the discovery of piezoelectricity.

Some common pyroelectric materials such as tourmaline, PZT, and PVDF are utilized for devices such as thermal sensors. There have been some studies into these materials for power generation, where the theoretical efficiency of power generation could be at 50% or higher. Additionally, pyroelectric materials have demonstrated their use in a process called Pyroelectric fusion. The pyroelectric properties of the crystals used in this particular experiment were used to cause nuclear fusion of deuterium into Helium-3. While this makes for a good academic exercise, this method of fusion is very inefficient. However, the ability to make a "neutron generator" with these materials could point to other uses as research areas.

In the world of printed electronics, materials such as PVDF can be utilized in inexpensive temperature sensors. These printed sensors have the potential to be used on such items as produce (to monitor temperature during shipping), pre-packaged items such as those sold in coffee shops and corner markets (to track the shelf life of food items or monitor the recommended storage temperatures), and temperature-sensitive items such as chemicals. Development is actively being done to bring these types of sensors to the marketplace, with some of them testing in select markets.

Ferroelectric Materials

The final group is ferroelectric materials, which make up a very small subset of pyroelectric materials. In other words, materials that are ferroelectric are also pyroelectric and piezoelectric in nature. While the prefix of "ferro" usually means that a given material contains iron, this is rarely the case with ferroelectric materials. Ferroelectric materials exhibit a spontaneous polarization that can be reversed by applying an electrical field. When ferroelectric materials were discovered in 1920 by the scientist J. Valasek, they were thought to be a subset of ferromagnetic materials (materials that exhibit a permanent magnetic moment). Ferroelectric materials were determined to be a new set of materials, but the "ferro" prefix stuck as a label.

To understand ferroelectricity, we need to understand a couple of other types of polarization. The first type, dielectric polarization, occurs when polarization is directly proportional to the applied electrical field in a linear relationship. Paraelectric polarization is a non-linear relationship between the applied electrical field and the polarization response. Finally, ferroelectric polarization is characterized by a couple of properties. First, it is polarized even when there is no applied electrical field. When an electrical field is applied in the opposite direction, the polarization is reversed, giving what is called a "hysteresis loop." Finally, as the temperature is

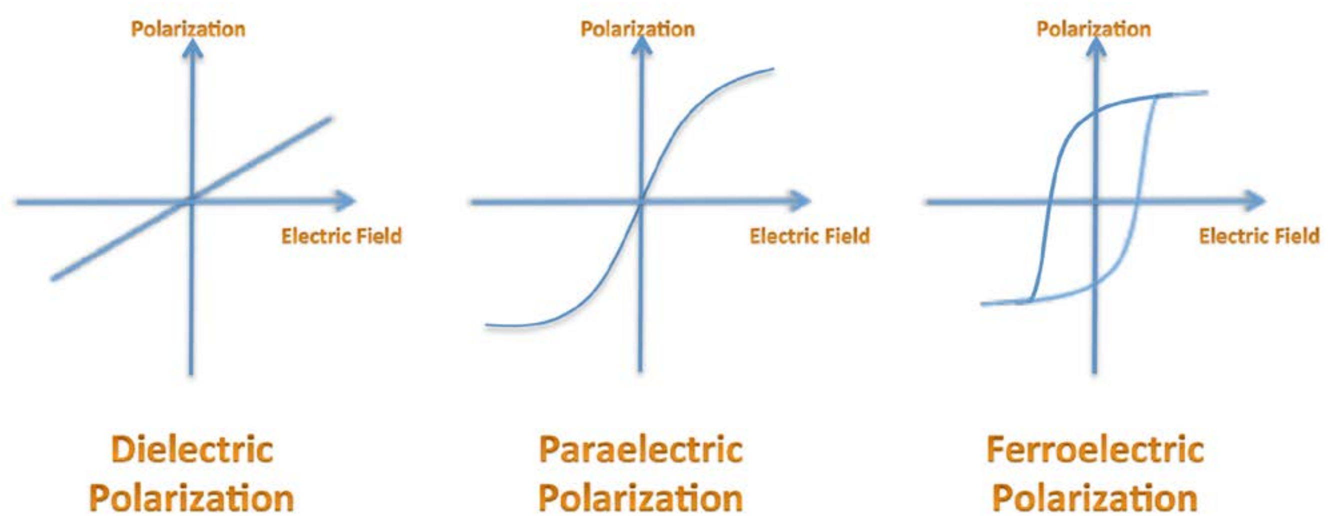

Figure 2: The ferroelectric effect.


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raised in these materials, the hysteresis loop becomes narrower. When a point called the Curie temperature is reached, the hysteresis loop closes and the material becomes paraelectric. Please refer to the Figure 2.

New ferroelectric materials are a hot area of research currently. Beyond the research materials, PZT, barium titanate, lead titanate, and PVDF are all ferroelectric materials that are commonly used in today's devices. One of the main ways this property is used in printed electronic devices is for rewritable memory. PVDF is typically used in conjunction with another polymer. The PVDF forms rigid crystalline structures, while the function of the copolymer is to act as flexible chains between the crystalline structures. When an electrical field is applied to regions of the film, the PVDF polarity orientates in relation to the field. The orientation of the crystalline regions' polarization can then be read as a "1" while the default polarization crystalline regions' polarization can be read as a "0," thereby creating a binary code for the printed memory. Please keep in mind that this is a simplified explanation and that suppliers of ferroelectric materials can give significantly more detail into the mechanism behind printed memory.

Multifunctionality

The nature of ferroelectric, pyroelectric and piezoelectric materials makes them very useful for multifunctional devices. One such example is the use of array of ferroelectric capacitors in infrared cameras. Such an array makes infrared cameras sensitive enough to detect temperature variations as little as 1/1000000 of a degree Celsius. They can also be used in heat and vibrational sensors, or in printed sensors for item-level purchases.. There are some devices on the market that utilize ferroelectric materials: gift cards, toys, and RFID tags that are readable by your smartphone or a scanner. The multifunctional properties of these materials are also useful in energy harvesting, where these materials are incorporated into solar cells and panels. Vibration caused by wind or changes in temperature can cause the materials to produce an electrical current that can be harvested in addition to the power generated by the solar cells. Another recent experiment tested these materials by incorporating them into the matting of a playground structure. As children played on the playground, the piezoelectric and pyroelectric properties helped to generate electricity. As the sun set, the energy stored during the day was used to power the lighting for the playground.

"Another recent experiment tested these materials by incorporating them into the matting of a playground structure. As children played on the playground, the piezoelectric and pyroelectric properties helped to generate electricity. As the sun set, the energy stored during the day was used to power the lighting for the playground."

Piezoelectric, pyroelectric, and ferroelectric materials have been studied and used for quite a long time. Their relatively low cost, ease of use, and multifunctional capabilities have made them the topic of research for use in various electronic devices, for over a century now. This group of materials is a prime example of how PE can utilize well established materials in next-generation devices. As our research advances in this field and the deposition methods improve, we can expect to see more of these multifunctional materials used in our conventional and disposable electronics. **PCB**

Josh Goldberg is a marketing specialist at Taiyo America Inc.

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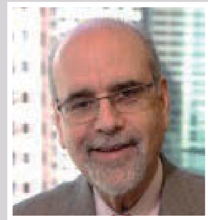

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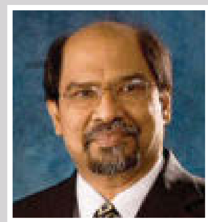

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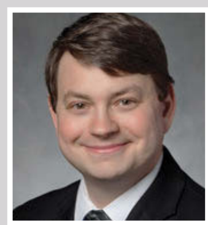

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PCB007 Market News Highlights

Conference Board ETI Up 6.3% in June

"The rapid increase in the Employment Trends Index in recent months suggests that strong job growth is likely to continue through the summer," said Gad Levanon with The Conference Board. "While the strong labor market signals an improvement in economic growth, the key factor is that the average productivity of workers will need to rise as well."

Global LCD TV Shipments to Gain 3% This Year

WitsView Research Director Burrell Liu noted, "TV panel pricing is expected to remain flat or increase throughout August into September but this is still yet to be fully determined, as end sales performance and whether vendors' inventories are piling up will still all make a difference. The same will apply to notebook and monitor panels."

Consumer Confidence Index on the Rise

The Conference Board Consumer Confidence Index, which had increased in May, improved again in June. The Index now stands at 85.2 (1985=100), up from 82.2 in May. The Present Situation Index increased to 85.1 from 80.3, while the Expectations Index rose to 85.2 from 83.5 in May.

Consumer Healthcare Sensor Market at $47.40B by 2020

The sensor market in Consumer Healthcare is expected to reach $47.40 billion by 2020 growing at an estimated CAGR of 5.56% from 2014–2020. The developments in sensing technologies can help to increase the trend of continuous patient monitoring, which can result in reduced healthcare costs and improved treatment outcomes.

Solar Makers Seen to Boost Production Capacity

Solar PV supply chains are starting to see demand in China whither, while demand in the United States and Japan remain stable, according to EnergyTrend. As such trends occur, solar supply chains are expected to increase production capacity in the second half of 2014.

Global 3D Printing Forecast to 2019

The 3D printing market has seen rapid growth in recent years due to its increasing applications across different sectors such as consumer products and electronics, automotive, medical, industrial, and aerospace. Decreasing cost of 3D printers and its increasing adoption across the government and education sectors is further expected to spur the demand in the coming years.

Tablets to Bridge the Gap with Smartphones

New analysis from Frost & Sullivan finds that by 2016, the use of smartphones is expected to decrease from the current levels of 66% to 58%, while tablets are expected to increase from 49% to 56%.

PC Monitor Market Sees Sluggish Q12014

"Despite the overall decline, the shipment totals were stronger than the forecast of 31 million units," said Phuong Hang, program director, Worldwide Trackers at IDC. "Geographically, Japan and the Middle East and Africa (MEA) regions delivered the largest gains during the first quarter while Dell and HP both experienced solid shipment growth."

Health Monitoring Market to Reach $2.50B by 2020

The machine health monitoring market is expected to reach $2.50 at a CAGR of 7.16% from 2014 to 2020. Machine health monitoring is an uninterrupted assessment of the equipment and machinery. Machine health monitoring system can be implemented to reduce plant operating costs by optimizing maintenance activities and lowering the instances of unscheduled outages. Thus it helps in reducing the overall maintenance costs and improving the lifetime of equipment.

Digital Signage Revenue Falls Flat

The digital signage industry is facing a formidable challenge from cheaper, conventional TV panels that replace specialized custom products that long have differentiated the professional displays market.

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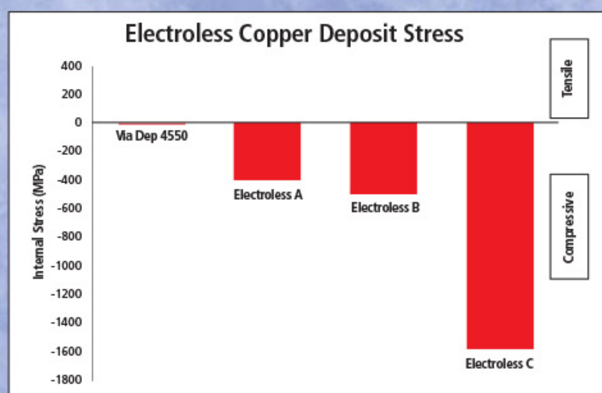

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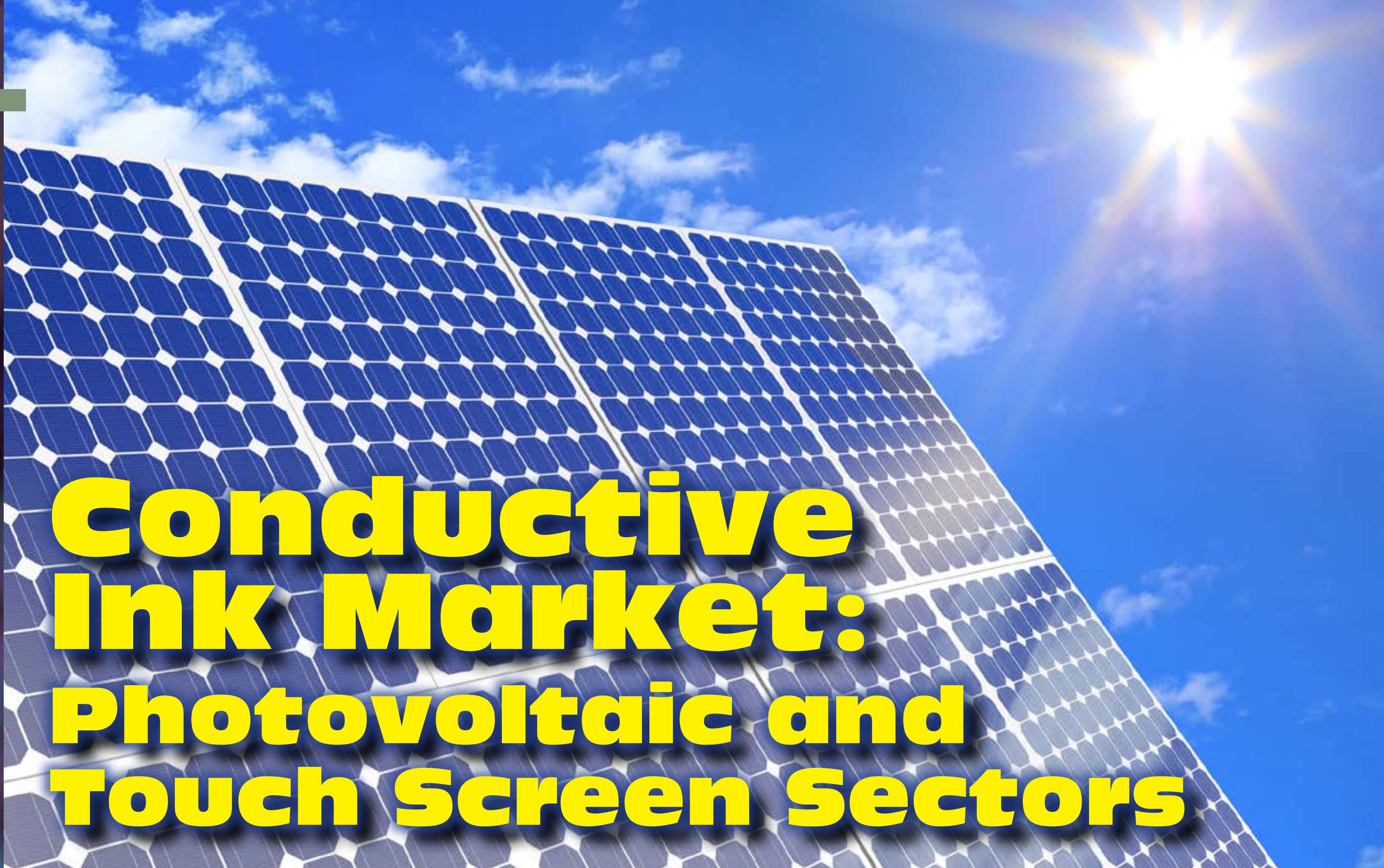

Conductive Ink Market: Photovoltaic and Touch Screen Sectors

by Dr. Khasha Ghaffarzadeh
IDTECHEX

Photovoltaic Market

The photovoltaic market is a large, addressable market, which is growing again after several years of difficulty, when the prices crashed from $3.5/W in 2008 to $0.75/W in 2012. This period of overcapacity was characterised by many companies going bankrupt, closing, or selling.

However, the market is showing signs of recovery.

Each crystalline silicon PV wafer carries 150–200 mg of screen-printed silver. This is mostly in the form of bus bars, but also fingers and back electrodes. Screen printing is a robust technology that is cost competitive. However, the high price of silver has compelled companies to look for alternatives to silver as the high bill of materials can constitute up to 30% of the wafer cost.

Plating is the main threat, although it is still at an experimental stage. Despite this, many industry players expect to be phased-in in a significant way over the coming decade. A common approach is to print a fine seed layer (i.e., inkjet print), plate nickel as a diffusion barrier and then thicken it with copper. Note that the silver nitride layer will have to be opened up to enable plating. In general, plating wins on reducing the bill of materials, but loses on high process costs as it is more complex than screen printing. IDTechEx estimates that plating will take approximately 20% market share by 2024.

Touch Screen Market

The touch screen market is booming. Conductive pastes are used to make the edge (or frame) electrodes, as shown in the image below. The edge electrodes can be made by sputtering followed by patterning or by printing. The former method gives high resolution but can be expensive due to the subtractive nature and the number of steps involved. This method is most common in Korea. The latter method is lower cost but L/S resolution is typically 100/100. This method is most common in China and Taiwan. Our industry input confirms that 18–20 grams of conductive paste is consumed per one square meter of transparent conductive. It is noted that the trend in the industry is to narrow the frame, and the consumer will be demanding L/S

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below 30/30. This can either be met by sputtering (which remains expensive) or new types of printing such as gravure offset and inkjet (if thickness can be increased).

Other Markets

Conductive inks and pastes are used in a variety of other applications including circuit boards, membrane switches, automotive, sensors, RFID antennas, etc. Here are just a few application examples of these sectors:

Printed Circuit Boards: Silver paste is screen printed on printed circuit boards to fill in vias. Silver migration is a challenge, which is why many considering silver/copper or copper pastes for this market.

Cars: The automotive sector is a large target market for conductive paste already. In the exterior, screen printed silver paste is used in window heaters, while in the interior seat sensors, seat heaters, airbag dispatchers, dashboard illumination, overhead consoles (in-mould electronics) are used.

Membrane Switches: Membrane switches are already a large and established (though declining) business for conductive paste. Keyboards for PC, notebooks and home appliances are amongst the leading applications. **PCB**

Dr. Khasha Ghaffarzadeh is the head of consulting at IDTechEx.

VIDEO INTERVIEW

Sunstone's New Initiatives

by Real Time with...IPC APEX EXPO 2014

Publisher Ray Rasmussen sits down with Sunstone Circuit's Marketing Manager, Mathew Stevenson, to discuss some of the company's new initiatives, revamped website, and more!

realtimewith.com

Mil/Aero007 News Highlights

Murrietta Circuits Nets Raytheon Five Star Supplier Award

Andrew Murrietta, CEO and co-owner of Murrietta Circuits, announced that his company has been awarded Raytheon's Five Star Supplier Recognition Award for the second year in a row. He says, "This is truly overwhelming for me and the rest of the Murrietta team. I know we have all worked hard to make this happen and we are so pleased and proud we were recognized again this year."

IPC Lauds U.S. Rule on Military-related PCBs

Following years of advocacy work to clarify the treatment of printed circuit boards (PCBs) under International Traffic in Arms Regulations (ITAR), IPC is applauding the U.S. Department of State's final rule for Category XI for Military Electronics of the United States Munitions List (USML). Published today, the new rule states that PCBs "specially designed" for defense-related purposes will be controlled under USML Category XI. Additionally, any designs or digital data related to "specially designed" PCBs will be controlled as technical data.

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.

Merlin Flex Earns SC21 Bronze Award

Flexible and flex-rigid PCB manufacturer Merlin Flex Ltd., based in the Northeast of England, has been awarded a prestigious SC21 Bronze award. The SC21 programme has become a benchmark for supply chain excellence evaluating current business practices against rigorous international standards in quality, service, and business management.

Multilayer Technology Completes AS9100 Audit

Multilayer Technology of Irving, Texas is pleased to announce it has successfully completed a scheduled AS9100C + ISO9001: 2008 conducted in May 2014.

FTG Tianjin China Ships 10,000th Flight Deck Product

Firan Technology Group Corporation has shipped its 10,000th aircraft flight deck product from its facility in Tianjin, China. "It has been amazing to watch the development and growth of our new facility in Tianjin. The team there has learned so much and has developed world-class skills in illuminated cockpit products," stated Brad Bourne, president and CEO, FTG Corporation.

NASA Launches Mission to Monitor Earth's Breathing

NASA's Orbiting Carbon Observatory-2 (OCO-2) aims to locate Earth's sources of and storage places for atmospheric carbon dioxide, the leading human-produced greenhouse gas responsible for warming our world and a critical component of the planet's carbon cycle.

DoD Spending Driven by Geospatial Tech Innovation

The DoD is leveraging innovations in geospatial technologies to ensure commanders at every level have a deeper understanding of evolving operational environments. "After engineering and integration, improvements in dissemination and targeting will command the most attention, with spending in 2018 likely to stand at $712.6 million and $579.4 million, respectively," said Industry Analyst John Hernandez.

Power GaN Market to See 80% CAGR through 2020

Overall, 2020 could see an estimated device market size of almost $600 million, leading to approximately 580,000 x 6 wafers to be processed. Ramp-up will be quite impressive starting in 2016, at an estimated 80% CAGR through 2020, based upon a scenario where EV/HEV begins adopting GaN in 2018–2019.

Global Commercial Satellite Imaging Market Forecast

This report analyzes the commercial satellite imaging market on a global basis, with further breakdown into various sub-segments. It provides thorough analysis and market growth forecast of the global commercial satellite imaging market, based on its applications, end-use industry, and geography for the period from 2013–2019.

Controlling the ENIG Process for Optimum Efficiency and Performance

by Michael Carano
OMG ELECTRONIC CHEMICALS

Introduction

In last month's Trouble in Your Tank, different levels of corrosion in the nickel deposit were presented. In addition, the suggestion was made that mid-phosphorous content EN process was more beneficial with respect to solderability, as opposed to a high phos content nickel deposit. Certainly, concerns with corrosion of the nickel (with lower phos) were allayed as long as the proper process controls were in place. Ideally, the ENIG process must provide the optimum in solder joint reliability while operating at the highest level of cost efficiency. All too often, process parameters that have the most influence on these critical attributes are poorly understood. An example of poor control is shown in Figure 1. The gold deposit has been removed in order to expose the electroless nickel surface.

It is very difficult to discern any anomalies in the nickel deposit without removing the gold.

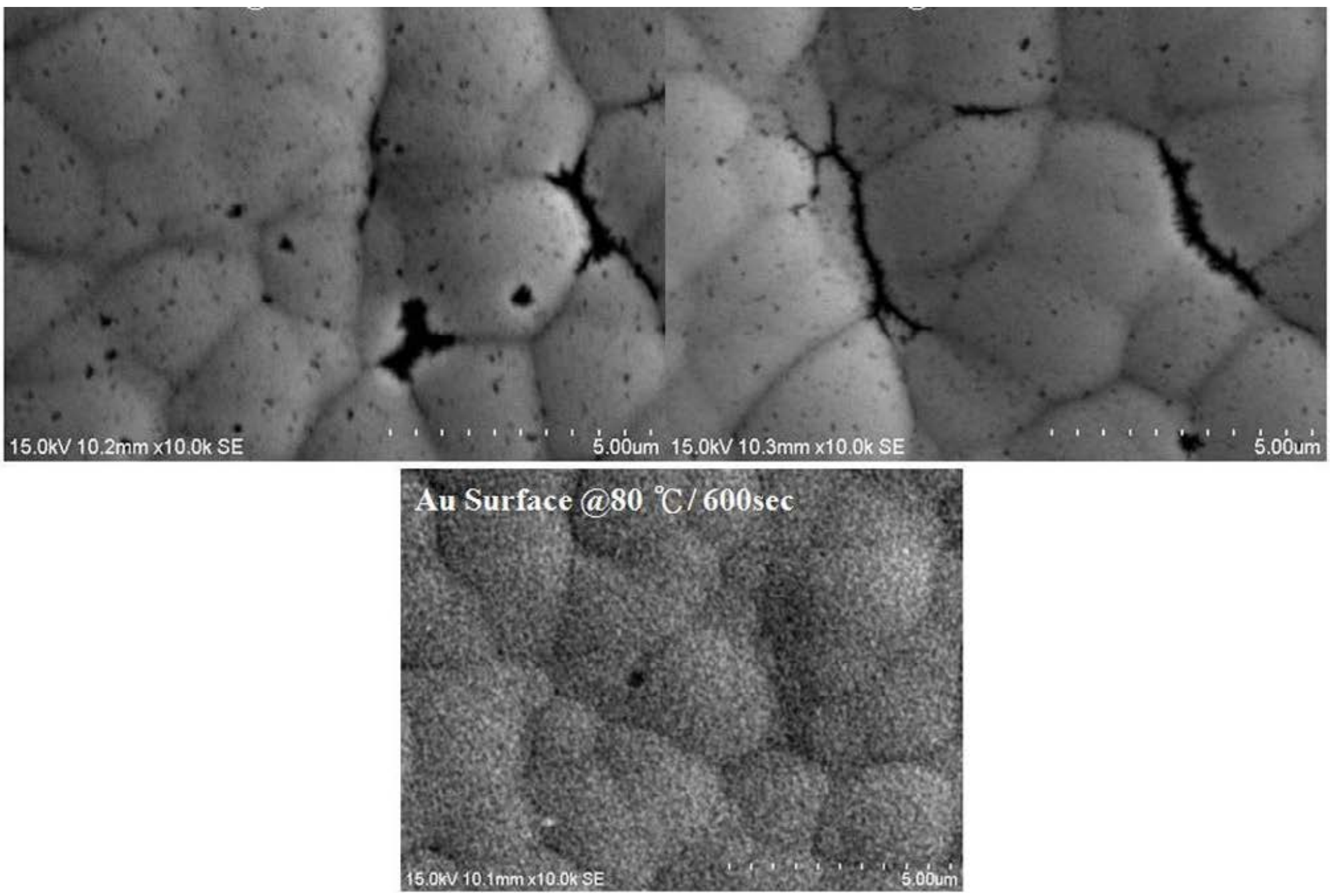

Figure 1: The top two photos show the severe corrosion in the nickel deposit. The bottom photo is the surface with the gold deposit over the nickel.

It is clear from the SEMs in Figure 1 that there is significant corrosion on the electroless nickel surface. Obviously, this is an unacceptable situation, and in order to prevent it one must work harder to optimize and control the electroless nickel-immersion gold process. Some of these factors will now be presented in detail.

Critical Electroless Nickel Features

1. Phosphorous content control in the electroless nickel deposit. Don't underestimate this important parameter.
2. Stabilizers in the EN solution influence phosphorous content in the deposit.
3. Phos content has strong influence on solderability, immersion gold deposit thickness and potential for hyper-corrosion.

Let's look at these points in a little more detail.

As I have written in this monthly column on many occasions, operating the chemical processes within the process window is the key to consistent and predictable performance. After all, your customers should expect no less from you. So with respect to #1 above, it is recommended that the EN process be able to maintain a reasonably tight window with respect to phos content through five metal (MTOs) turnovers in the nickel solution.

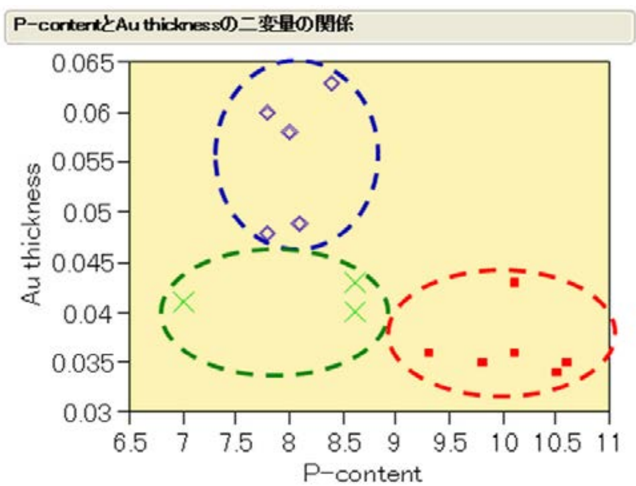

Figure 2: Influence of EN solution pH and phos content of EN deposit on gold plating thickness.

Figure 2 provides a good summary of what happens under certain plating conditions. Note that X (green) refers to an EN formulation with the operating pH kept at 5.3. The area of the chart outlined in red refers to an EN process that operates at a 4.8 pH, but co-deposits a higher level of phosphorous in the EN deposit (due to additional influences). The blue refers to the preferred range of phos (7–8.5%) and a pH of 4.8. Note that under these operating conditions (as well as the proprietary nature of the EN solution) the blue process gave a higher immersion gold thickness that was required to meet the IPC-4552 specification. It should be noted the thicknesses of the gold shown in the red area are much too low to meet the minimum specification as listed in IPC-4552. And this was primarily due to a higher EN solution operating pH. There is one caveat here. Quite a few OEMs and fabricators will accept lower gold thicknesses. I am not advocating such an approach without the need for further study.

The phosphorous level in the deposit of most EN processes is inversely related to the pH of the working bath; as the bath pH decreases, the phosphorous level in the EN deposit increases. Each 0.1 decrease in bath pH units will increase the phosphorous level of the deposit by about 0.5 %. Close pH monitoring will improve not only corrosion resistance of the nickel deposit, but will also improve the gold plated distribution across the panel.

The Use and Control of Stabilizers in the EN Solution

The type and concentration of stabilizers in the EN plating solution exert a strong effect on the phosphorous content of the deposit. It has been well documented that some stabilizers, while performing the intended effect of preventing nickel plate-out, may actually negatively influence the amount of phos in the deposit. And as was stated earlier, the higher phosphorous content can actually reduce the amount of gold that is deposited on the nickel (via the galvanic or displacement reaction). As a consequence, some fabricators, in an effort to increase the gold thickness, will increase the dwell time in the immersion gold solution. The outcome is usually corrosion spikes in the electroless nickel deposit.

Some Interesting Interactions

The phosphorous content of most commercially available EN processes tends to increase with bath age; this is due to the incremental reduction in plating rate from by-product build-up. Typically, the phosphorus level will increase by up to 0.5% per MTO. In addition to this ordinary change in deposit phosphorous content, the level can also be altered through the use of specific additives as well as through modification of certain operating parameters. This is precisely why it is important to understand the EN system one is using and be provided the proper control procedures to maintain the phos content within a tight operating window.

Phosphorous and Solderability

There are some who believe that the key to eliminating black pad or hyper-corrosion rests with operating an EN solution that allows for higher phos content in the nickel deposit. Some advocate a phos content of upwards 11–12%. I disagree for reasons stated in previous columns. Again, the higher the phos content, the lower the immersion gold thickness. In addition, the solderability of the nickel surface is reduced as evidenced by previously published solder spread and wetting balance tests.

Summary

Manage the phosphorous content in the EN deposit. Higher phosphorous content will reduce immersion gold thickness. And, poor control of the phos content will cause higher-than-normal gold consumption as well. In addition, too low of a phosphorous content will lead to possibility of corrosion spikes in the nickel deposit. **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.

I-CONNECT007 FEATURE PANEL DISCUSSION

Printed Electronics Discussion

Sponsored by: Taiyo America

Publisher Ray Rasmussen moderates a discussion on the state of printed electronics today, with John Andresakis, VP of strategic technology, Oak-Mitsui; Scott Gordon, business development manager, DuPont Teijen Films; and Josh Goldberg marketing specialist, Taiyo America.

CLICK TO VIEW

PCB007 Supplier/New Product News Highlights

Enthone Six Sigma Black Belt Graduation Hits Milestone

Enthone Inc. is proud to announce the upcoming graduation of the company's 2014 Six Sigma Black Belt Class. The graduating class marks the tenth black belt training certification held in the Americas and the twenty-third class worldwide since the inception of the company-wide program in 2001.

Ucamco's Integr8tor v8.3 Now Available for Download

Integr8tor v8.3 offers a range of new, state-of-the-art features and tools that respond directly to those needs. One of these is a brand new tool that determines automatically whether holes should be drilled in sequential PCBs using laser or mechanical means.

Isola Introduces Tachyon-100G Laminates & Prepregs

Tachyon-100G laminates and prepregs enable line cards required to transmit 100 Gigabit Ethernet at data rates in excess of 25 Gb/s per channel. They have identical electrical properties as Tachyon; however, the Z-axis CTE on Tachyon-100G is more than 30%, making it more suitable for fabricating high-layer count, 0.8-mm pitch line cards with heavy 2-ounce copper inner layers.

FASTechnologies Completes Installation at Alpha Circuits

PCB drilling software solutions provider, FASTechnologies Corporation is pleased to announce the successful installation of the company DNC UltraServer, SmartParts Classic, and SmartParts Cassetting at Alpha Circuits in Elmhurst, Illinois.

Fuji Recognizes National Graphics Supply

During the recent Japan Electronics Packaging and Circuits Association Exhibition (JPCA) in Tokyo, Japan, Fuji Film recognized National Graphics Supply, LLC for their excellent service and success in providing Fuji Film products to the National Graphic Supply customers in the U.S. and Canada.

Isola Relocates Asia-Pacific Technology Center

The new Taiwan Technology Center, which will support the increased demand for Isola's high-speed digital materials and RF/microwave and millimeter wave substrates in the Asia-Pacific region, will be co-located with the company's flagship Advanced Engineered Dielectrics Manufacturing Center in Yangmei, Taiwan.

Orbotech Acquires SPTS; Accelerates Growth

Orbotech Ltd. has announced the signing of a definitive share purchase agreement to acquire SPTS Technologies Group Limited (SPTS), a U.K.-based leading manufacturer of etch, deposition and thermal processing equipment for the microelectronics industry, from European private equity firm Bridgepoint and others.

Intercept Expands to India with Tecnode Solutions

Intercept Technology Inc. announces its newest authorized reseller, Tecnode Solutions (P) Ltd. Tecnode's primary goal is to expand its RF and microwave solutions portfolio by selling Intercept's PCB, RF, and hybrid design software applications throughout India.

Plasma Treatment Can Improve Conformal Coating Adhesion

Nordson MARCH, a Nordson Company, and global leader in plasma processing technology, announces that recent studies have shown that plasma treatment of printed circuit boards prior to conformal coating improves the adhesion of the coatings.

Orbotech, Ion Pact Supports Declassification Proposal

Orbotech Ltd. and Ion Asset Management Ltd. have reached a mutual agreement under which Orbotech has agreed to call an Extraordinary General Meeting not later than August 15, 2014 to allow its shareholders to consider a proposal to declassify the Orbotech Board of Directors.

Pressure in Hot Roll Lamination of Dry Film Photoresist

by Karl Dietz
KARL DIETZ CONSULTING LLC

Lamination Pressure

In lamination, we are trying to achieve good contact between the resist and the substrate surface by making the resist flow to conform to the surface topography. Flow is achieved by lowering the resist viscosity through heat, and by applying a pressure differential for a certain time to cause the flow. The the photoresist is exposed to these conditions depends on the rpm of the hot rolls, the hot roll diameter, and to some extent on the pressure as it affects the footprint width in the nip. The pressure may be transmitted to the lamination rolls pneumatically, hydraulically, mechanically, or a combination of these means. This column focuses on pressure as an important variable that needs to be controlled and optimized.

Non-uniform pressure can cause a variety of problems such as dry film resist wrinkles shown in Figure 1.

If the hot roll surface has a localized recessed area (e.g., a cut caused by a knife during manual trimming of film), this will be a spot of low pressure, resulting in poor resist conformation to the board surface, which in turn can cause opens in a print and etch process.

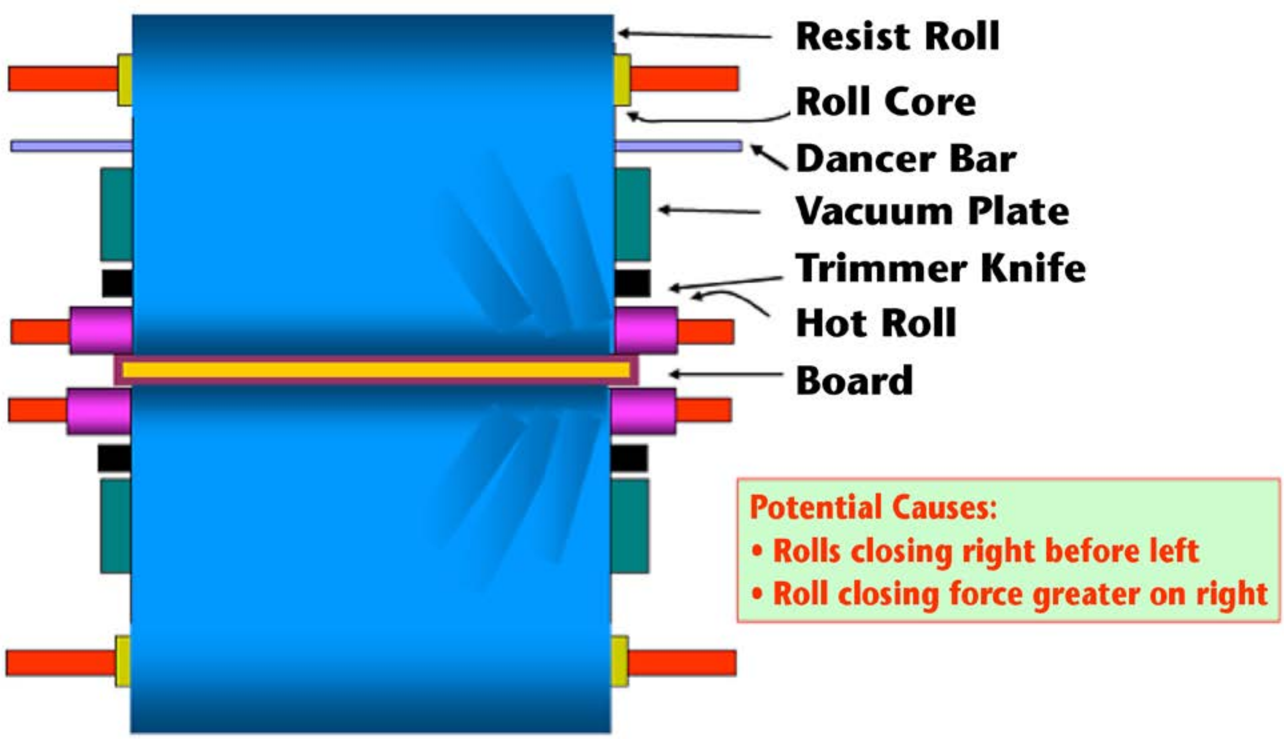

Figure 1: Lamination wrinkles pointing to one side.

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Conversely, if there is a protrusion on the roll surface (e.g., caused by a particle adhering to the roll surface) this becomes a spot of high pressure, which causes resist thinning that can lead to a variety of defects.

It is well understood that higher lamination pressure will result in improved dry film resist conformation to the board surface. However, there are practical limitations to increasing the lamination pressure due to the design of a particular model of automatic cut sheet laminator. Even if a high pressure setting is compatible with the design of the laminator, it may be difficult to take advantage of the higher pressure because the lamination rolls bend under the increased pressure. Roll bending results in an uneven roll footprint on the resist. The footprint is narrow at the center of the rolls and wider at the ends. This means that the pressure on the resist at the center is less than at the ends (Figure 2).

Laminator suppliers are aware of this phenomenon and try to build the rolls as sturdy as is practical. Residual roll bending can be compensated for with rolls which are "crowned." A crowned roll has a rubber covering which is thicker in the center than at the edges and changes gradually from center to edge, resulting in a curved profile (Figure 3). In our studies, we found that the correct amount of crown for an ASL-24 laminator was in the range of 3–4 mils (75–100 microns).

Figure 4 shows the results of lamination test at two different pressure settings: with straight

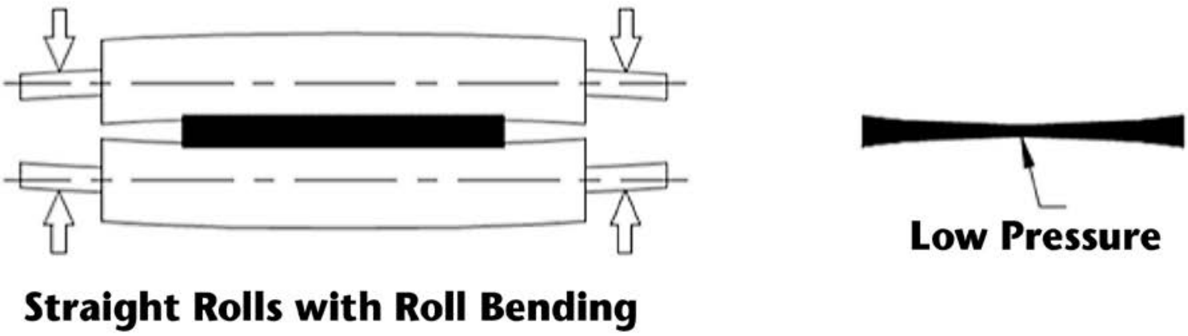

Figure 2: Nip pressure profile with straight rolls.

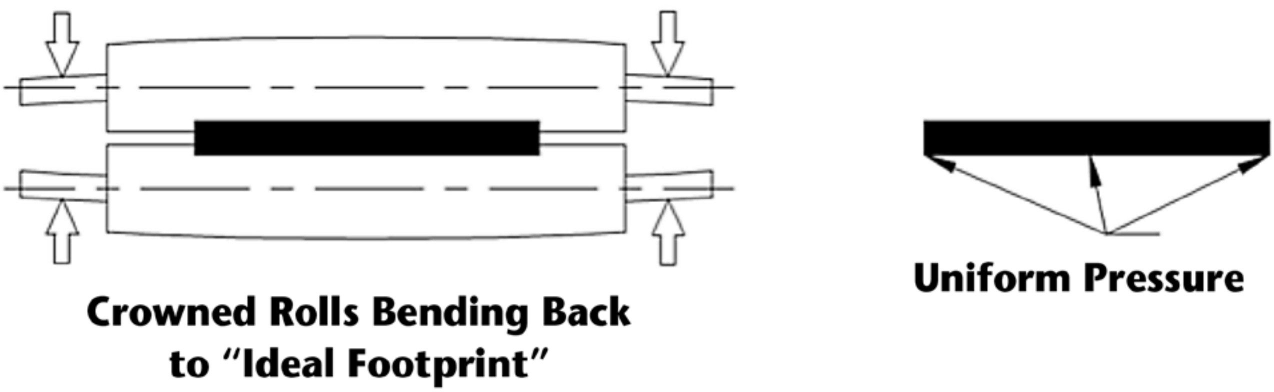

Figure 3: Nip pressure profile with crowned rolls.

rolls and with crowned rolls. "Open" defects as detected by AOI were plotted as a function of the location on the board. High columns indicate a high occurrence of opens. The results of the "base" condition (i.e., low pressure and straight rolls) are shown in the upper left hand corner of Figure 4. One can see the high rate of defects in the center of the board, in machine direction, due to the bowing of the rolls. The higher pressure scenario, still with straight rolls, is shown on the lower left side of Figure 4. The higher pressure give a lower overall defect rate, but the pattern of higher defects in the center line due to bowing remains visible. The result shown on the upper right-hand side of Figure 4 shows the beneficial effect of crowned rolls: The defect rate is now more even across the board, with some random defects remaining. Adding high pressure to this condition as shown on the lower right hand side of Figure 4 then yields the overall best results. **PCB**

Karl Dietz is president of Karl Dietz Consulting LLC. He offers consulting services and tutorials in the field of circuit board and substrate fabrication technology. To view past columns or to reach Dietz, click here. Dietz may also be reached by phone at (001) 919-870-6230.

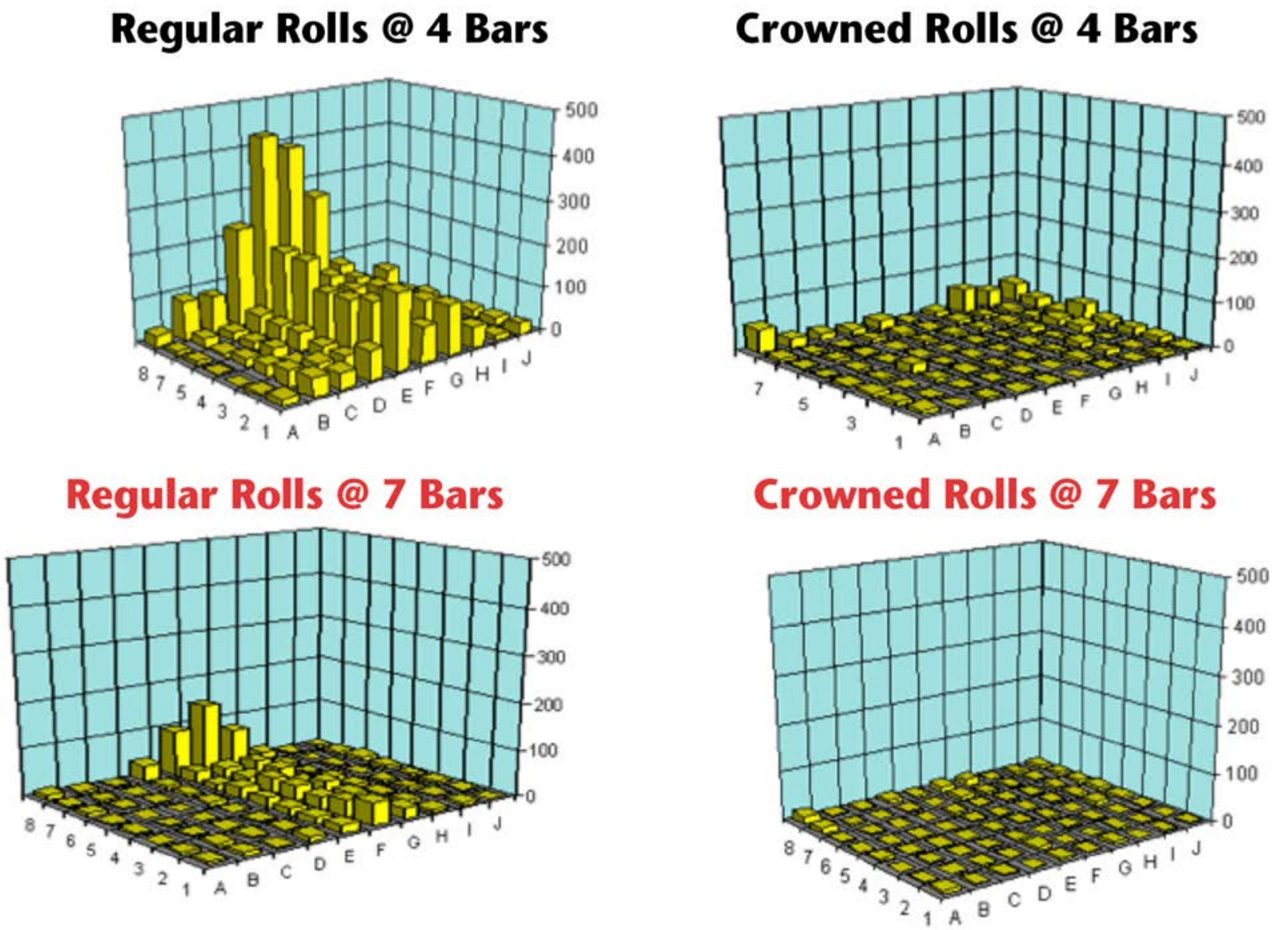

Figure 4: "Open" defect plots for different pressure settings and different roll construction.

TOP TEN

PCB007 News Highlights This Month

1 Schweizer CEO Reappointed Board Member of ZVEI

At the general meeting of the Zentralverband Elektrotechnik und Elektronikindustrie (ZVEI), the German electrical and electronic manufacturers association, in Munich, Germany, Dr. Marc Schweizer, CEO of Schweizer Electronic AG, was reappointed a member of the board of ZVEI.

2 Electronics Industry Leaders Meet with Policy Makers in D.C.

A healthy electronics industry is critical to the economy and national security of all nations. That's why 17 IPC member-company executives gathered in Washington, D.C. to meet with senior policy makers as part of IMPACT 2014: IPC on Capitol Hill. Through a series of meetings, the executives educated lawmakers about the needs of our industry.

3 IPC: PCB Industry Growth Slows in May

"While sales growth is slowing, declining orders pushed the book-to-bill ratio below parity after just two months of positive ratios," said Sharon Starr, IPC's director of market research. "This setback in the industry's recovery is likely to be short-lived, given the positive economic outlook for North America this year," she added.

4 Newbury Begins Redevelopment Program

Newbury Electronics has begun the initial phase of its redevelopment program early this month. West Berkshire MP Richard Benyon recently visited Newbury's premises to learn more about its redevelopment of the site, which will ultimately provide increased production space, new offices, and deliver savings in both water and electricity consumption.

5 PCBs Enumerated at Category XI of USML

The U.S. Department of State published a final rule that enumerates PCBs in Category XI for Military Electronics of the United States Munitions List (USML). This is a significant win for IPC which has advocated for the enumeration of PCBs on the USML.

6 Sunstone Circuits Names Hammer QA Manager

Sunstone Circuits, the leading PCB prototype solutions provider, has named Dennis Hammer as quality assurance manager. In this position, he will play a vital role in the management of product quality, continuous improvement, and process analysis.

7 Global, China Advanced Rigid PCB Industry Report

The PCB industry is fairly mature, with the growth rate generally not more than 6%. The output value of rigid PCB vendors has long been declining—the year 2012 witnessed hard times for rigid PCB vendors at a time when the smartphone and tablet PC market showed unexpectedly rapid growth. This sent rigid PCB vendors into a fierce price war, leading to a drop in profit and revenue.

8 TTM Shanghai Earns Zero Defect Award from Spansion

TTM Technologies, Inc. announced that its Silicon Platforms facility in Shanghai received the World Class Supplier—Zero Defect Award from Spansion Inc. on June 16, 2014 for supplying top quality, zero defect substrate products in 2013.

9 Merlin Circuit Installs Latest ITC Via Plugging Machine

Flintshire-based Merlin Circuit Technology has completed the installation and testing of the latest via plugging machine supplied by ITC. The THP35 is the most advanced system currently available and gives the ability to reliably fill all via types by way of its vacuum head.

10 Colonial Committed to IP Safeguarding; Earns IPC-1071QML

IPC's Validation Services Program has awarded its first IPC-1071 Qualified Manufacturers Listing (QML) to Colonial Circuits Inc., a full-service printed board manufacturer in Fredericksburg, Virginia. The facility underwent an intensive audit based on IPC-1071, Best Industry Practices for Intellectual Property Protection in Printed Board Manufacturing.

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.

Advancements in Thermal Management 2014
August 6–7, 2014
Denver, Colorado, USA

Philadelphia Expo & Tech Forum
August 12, 2014
Cherry Hill, New Jersey, USA

West Penn Expo & Tech Forum
August 14, 2014
Monroeville, Pennsylvania, USA

IPC Southeast Asia High Reliability Conference
August 20, 2014
Penang, Malaysia

NEPCON South China
August 26–28, 2014
Shenzhen, China

Vietnam Manufacturing Expo
August 27–29, 2014
Hanoi, Vietnam

Electronics Assembly
August 27–29, 2014
Hanoi, Vietnam

Assembly Technology Vietnam
August 27–29, 2014
Hanoi, Vietnam

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
Phoenix, Arizona, USA

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PCB007 Presents
the pcb magazine

The PCB Magazine® is published by BR Publishing, Inc., PO Box 50, Seaside, OR 97138

August 2014, Volume 4, Number 8 • The PCB Magazine© is published monthly, by BR Publishing, Inc.

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September:
New Concepts and Emerging Technologies for PCB Fabrication

October:
End Markets for PCBs

November:
Medical Applications