

February 2015

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FINISHES

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February Featured Content

Surface Finishes

Industry experts from OMG Electronic Chemicals, Uyemura, Atotech and the University of Leicester are on hand this month to dive deep into surface finishes, from OSPs for mixed-metal finishes to cutting-edge high-reliability surface finishes.

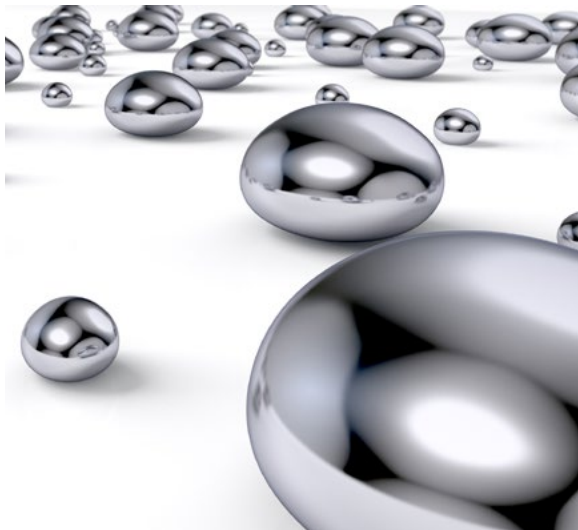
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by Michael Carano



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by Prof. Karl Ryder, Dr. Andrew Ballantyne, Dennis Price and Tom Perrett



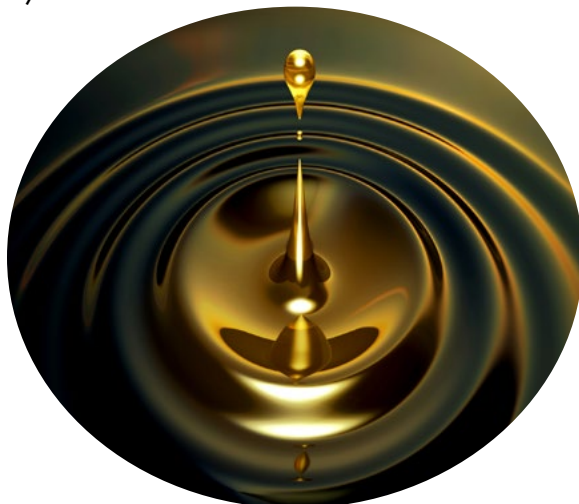
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by George Milad



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by Rick Nichols



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Bits and Pieces

by Ray Rasmussen

I-CONNECT007

Something New at I-Connect007

Probably the biggest news from our team is our very soon-to-be-launched new website. Using all the latest and greatest web technology, we've developed the site to make it really easy for our readers to find what they're looking for and we've integrated the latest advertising tools to help sellers and buyers quickly find each other. This fast and user-friendly site, with over 80,000 news items, articles and columns, is the industry's most significant information resource. Let us know how you like it.

2015 also bodes well for the industry. With just about every leading indicator pointing north, it looks like we're in for a nice ride. Markets that we've only dreamed about in the past are beginning to emerge. Moving past the hype, shows like CES and the North American International Auto Show have laid out the path forward with a plethora of new technologies and requirements for technology. Electronics are everywhere!

Another boon for the economy is the price of energy, in particular, oil. I read an article recently that said the low gas prices could save the U.S. economy up to \$300 billion this year.

That's not bad. Lower fuel prices mean lower energy and shipping costs and less pressure on wages as consumers keep more of what they earn. The bad news is that many believe one reason for the low prices is an attempt by OPEC to crush higher-cost producers in the U.S. and Canada. Even so, I'm hopeful that lower energy costs will ultimately help stimulate the global economy, increasing growth, overall. Once the global economy kicks into gear, demand will increase and oil prices will rise again, incentivizing domestic producers.

I can't wait until we're all electric. Nuclear, hydro, wind and solar, and someday, fusion: that's the way forward. That's what frees us from so many of the problems associated with petroleum. This is not a political statement, it's just common sense. Domestically produced clean energy just makes sense.

CES

I don't know if you've paid attention to what was going on at CES last month, but for me, it was the most interesting show I've ever seen. The products and the implications of those products were astounding!

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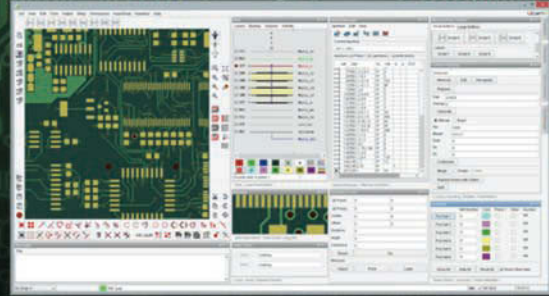


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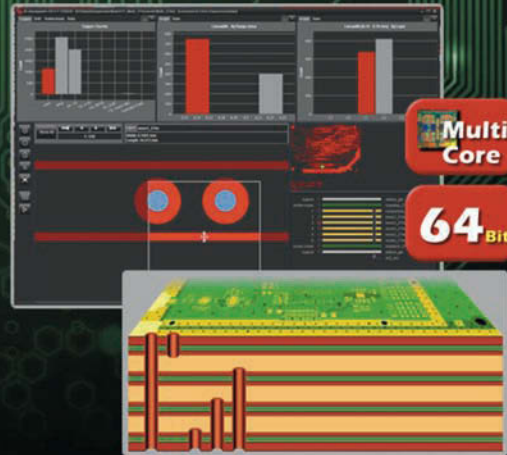
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BITS AND PIECES *continues*

This was the year of the wearables. With Apple's iWatch coming out soon, everyone was trying to get a jump on them with their own watch or wearable device. We've posted some of the broader announcements about markets, technologies and such but shied away from the plethora of product introductions. There was just too much stuff.

Dan Feinberg, our techno-geek editor at large, really got into it at this year's show, providing a solid flow of information for our readers. We only asked Dan to take a look at one product for us: the Voxel8 3D printer for electronics. And if you read our January issues of both [The PCB Magazine](#) and [SMT Magazine](#), you would have seen our coverage of [structural electronics](#). The exciting thing about this segment is that it allows electronics to be built into everything. We just have to figure out how to become part of this revolution and not a casualty of it.

Voxel8

As I mentioned, Voxel8 introduced a 3D electronics printer at CES. The important part of this story isn't just the printer and its implications for the electronics industry as we know it, but rather, who's behind it. These are serious folks with serious money. Voxel8 isn't destined for the hobbyist market like most 3D printers. Instead, they've developed a product which will likely be a foundational piece of the coming revolution in structural electronics.

The company is a Harvard University spinoff and has some serious backing. Here is something from a [recent posting](#) on our website; you'll see what I mean.

...Voxel8 is collaborating with Autodesk on Project Wire, a Spark powered design tool for 3D printed electronics. Project Wire is a new design tool under active development at Autodesk that provides electronics and 3D printing enthusiasts with the ability to place components and route 3D wires.

Foxconn in Mexico

A couple of years ago, I mentioned Foxconn's consolidation of its Mexican operations in Ciudad Juarez. An article published by Open Democracy, [On the Border: Foxconn in Mexico](#), talks about this new operation with a focus on

the workforce. The article is slanted toward the workers and the conditions they face. It's certainly another side of the story that we in the trade press rarely cover. I found it interesting, and based on what I've been reading about the factory conditions in Asia, Mexico is just more of the same. Of course, it has to be said that not all companies are bad actors. And even in this case, we don't know the entire story. Most of them likely do a good job of caring for their workers. And most OEMs these days are under constant pressure from NGOs to improve conditions in the factories of their suppliers. The article only tells one side of the story, but it is interesting.

[IPC APEX EXPO](#)

Right around the corner, the IPC show and conference looks to be an exceptional event this year, with the show floor sold out and conference attendance up. As usual, we will be there in force with the I-Connect007 team conducting interviews, covering events and supporting our customers. IPC has listed over 300 new products from show exhibitors, so there's plenty to see. Please stop by our booth and say hello.

The Future

Barring some unforeseen political event or act of God, all signs point to a very good 2015 here in the U.S. Once Europe and Asia get back on track, and if energy prices remain relatively low, 2016 and beyond should bode well for the industry. The Internet of Things, printed electronics and 3D printing will certainly keep us all on our toes as we work to build the products of today while keeping an eye on the products of tomorrow. We have a lot to be thankful for in 2015.

See you at [IPC APEX EXPO!](#) **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](#).



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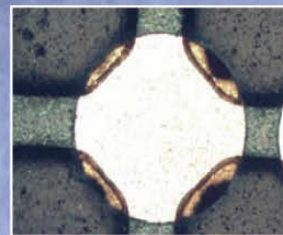
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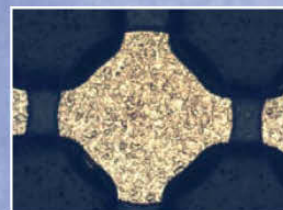
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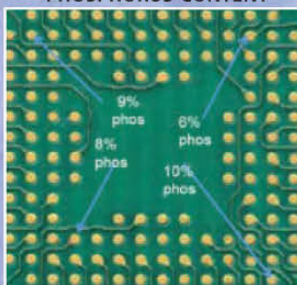


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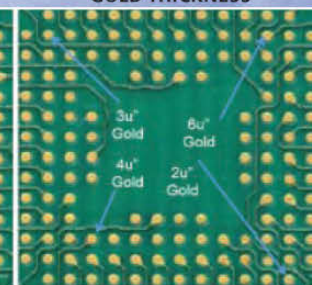
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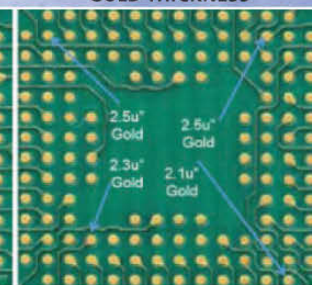
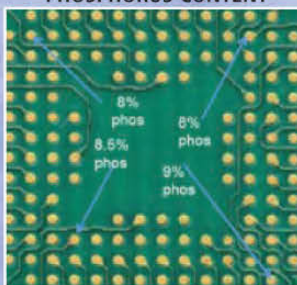
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OSP and Selective Electroless Nickel for Mixed-Metal Finish PWBs and BGA Substrates

by **Michael Carano**

OMG ELECTRONIC CHEMICALS LLC

Introduction

The documentation relating to the requirements for alternative surface finishes have been well publicized at many industry forums. Pressure to eliminate lead in electronics assemblies is forcing fabricators and OEMs to reevaluate their surface finish and joint attachment procedures. Many of the requirements, in fact, are obvious. Regardless, the PWB fabrication industry needs to work closely with contract manufacturers and end users to fully appreciate the true impact of technology trends. These trends are significant and include:

- ✓ Surface mount continues to increase at the expense of through-hole with finer and finer features.

- ✓ The use of non-tin/lead coatings and surface finishes will increase. Surface finishes such as electroless nickel/immersion gold, OSP and immersion tin will be utilized.

- ✓ With political movements toward banning lead in all electronic assemblies gaining significant momentum, lead-free solder pastes and wave solder materials will be adopted.

- ✓ The need for more robust solderable finishes under extreme environmental conditions including corrosive atmospheres.

- ✓ The alternative surface finishes must perform through multiple thermal cycles with less active pastes and fluxes.

- ✓ The use of multiple metal finishes on the same bare board will place new emphasis on the compatibility of coating with each other, and the actual assembly module.

- ✓ Increased I/O demand and reduced lead pitch will require much tighter controls over the processes used to fabricate the bare board.

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OSP AND SELECTIVE ELECTROLESS NICKEL *continues*

High I/O packages will test the process limitations in imaging, etching, solder mask and surface finishes.

✓ Chip scale packages and BGA will find increased use as an interconnect medium.

The trends listed above are only a snapshot of the many issues that fabricators and assembly companies face. However, those listed are the ones that most closely reflect the trends influencing the solderability of components and the bare board surface. This fact relates mostly to the actual selection and performance of the surface finish. Regardless, the finish must be able to perform under a variety of conditions, consistently and reliably. What is really interesting is the trend towards building circuit boards with mixed-metal finishes. Some refer to this as selective finishing. Here circuit boards are selectively finished with SENIG (electroless nickel-immersion gold). Other circuit features are finished (in most cases) with OSP. This presents several challenges both from an OSP standpoint and the proper selection of the electroless nickel and pre-plate surface preparation.

The process sequence for SENIG with OSP is shown in Figure 1.

Selective Electroless Nickel-Immersion Gold (SENIG)

Several years ago SENIG offered the promise of reduced gold cost due to the selective nature of the process. In this case gold would only be deposited on circuit features that would require wire bonding or act as touch pads or contacts. This type of process has become very popular for flip-chip applications. The remainder of the board would be processed through OSP (a.k.a., the mixed-metal finish). This promise has been met for the portable devices that are cost sensitive but require high reliability against shock-drop. The process sequence requires a secondary imaging step after soldermask. The photoresist protects the area on the circuit card from the ENIG processing steps. After the ENIG is plated the resist is stripped exposing the remaining circuit features which are bare copper. Here, the board is processed through the OSP line to complete the selective process. There are a few critical issues that the engineer must be aware when working with SENIG. First, it is best to employ a higher phosphorous content nickel (i.e., 10–12%) to provide the corrosion resistance necessary to withstand leaching from the photoresist as well as the acidic preplate chemistry of the

Selective ENIG with OSP-mixed metal finish

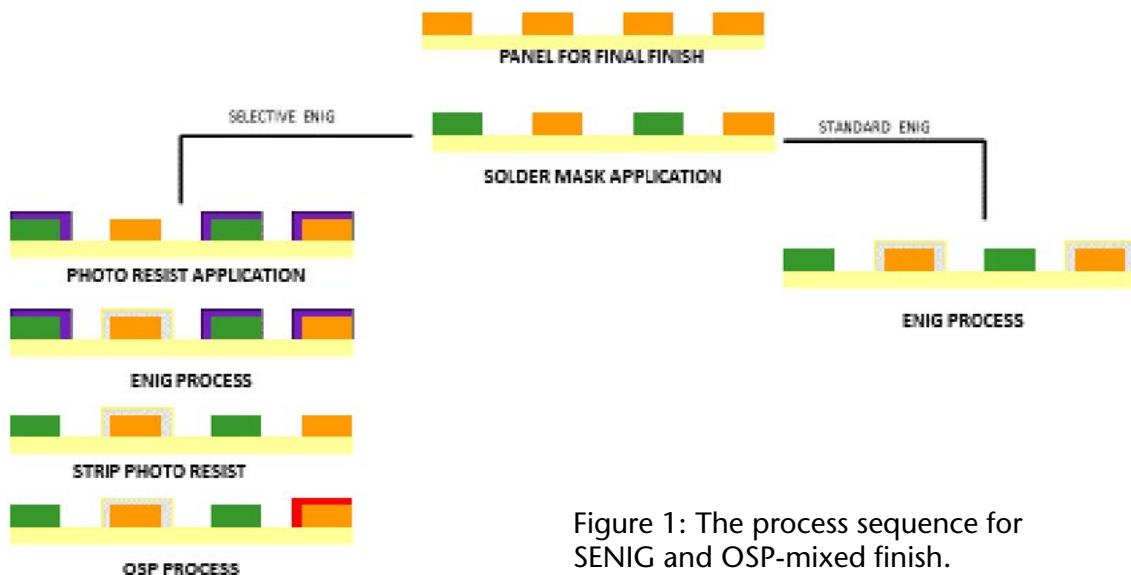


Figure 1: The process sequence for SENIG and OSP-mixed finish.

OSP. The second consideration is the ability of the OSP to properly coat the bare copper while leaving the gold deposit virtually untouched. Finally, the photoresist used in the secondary imaging step must be capable of withstanding the aggressive nature of the ENIG chemistry and temperatures. With respect to the photoresist used in the mixed-metal finish application, engineers should not assume that the primary resist used in the outerlayer processing sequence will be effective in such a processing environment. Consult the resist supplier for recommendations related to secondary image transfer (SIT). This type of resist must possess several qualities including:

- Good resist adhesion to multiple surfaces of different compositions such as laminate, copper, soldermask. Thus, many adhesion-enhancing process adjustments may not be practical because of stripping difficulties or resist embrittlement
- The resist has to survive rather harsh plating conditions, e.g., 20–30 minutes at 85°C, pH 4.5–4.8 in the nickel bath and equally high temperature in the gold bath, which can cause loss of adhesion
- The resist should be compatible with the various plating processes that are used in the selective plating process. Note that there is

a possibility of resist leach products that may interfere with the plating process. These leach products can lead to skip plating, peeling and poor solderability

Corrosion Resistance of the Selective EN

It is necessary that the nickel process employed in the SENIG/OSP process be highly corrosion resistant. Keeping in mind the various process steps outlined in Figure 1, the engineer should be wary of the potential for corrosion of the nickel (even with a thin deposit of immersion gold over the nickel). Immersion gold deposits are somewhat porous and it is possible for the pre-cleaning and micro-etching steps of the OSP process to attack and corrode the underlying nickel. (Note: At this point where the OSP is applied, the nickel-gold is exposed.) In addition, dry film leach by-products can cause corrosion of the nickel (Figure 2). The SEM in Figure 2 is that of a mid-phos EN process that is used for a selective application (6–9% by weight phosphorous).

One way to prevent such a condition is to employ a high phosphorous content electroless nickel process (generally phos content in the range of 10.2–11.5%). Figure 3 shows the preferred condition. Exposed nickel was subjected to dry-film leaching and OSP acid cleaning and micro-etching.

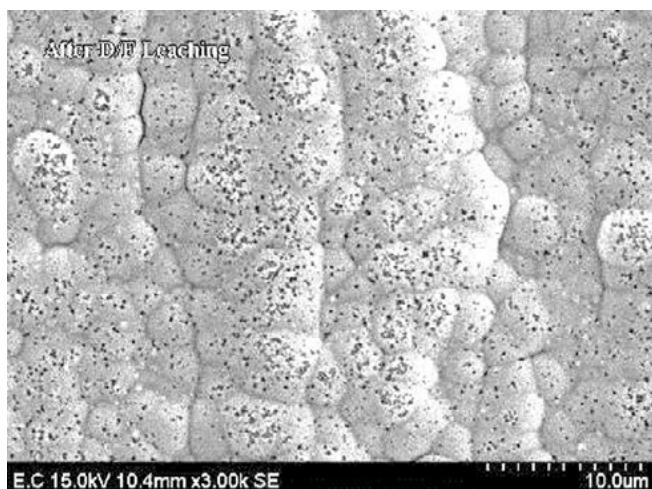


Figure 2: Mid-phos EN deposit that is susceptible to corrosion by resist leach products and acids and micro-etchants. Pitting in the deposit is due to corrosion of the nickel.

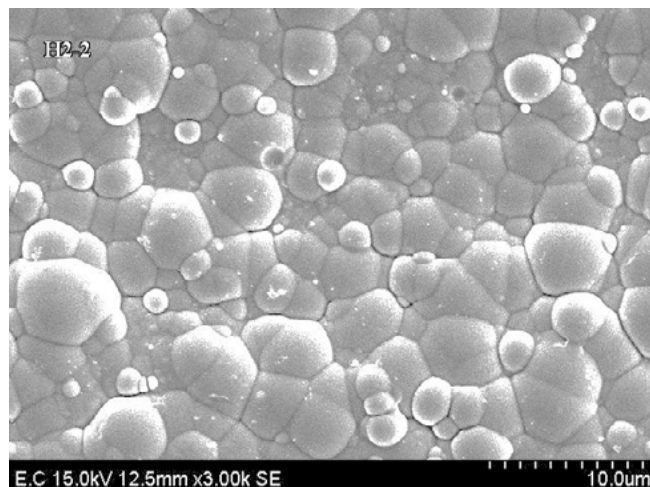


Figure 3: High-phos EN formulation designed for SENIG and mixed-metal finish applications.

OSP AND SELECTIVE ELECTROLESS NICKEL *continues***OSP for Mixed Metal Finishes**

With these caveats, the fabricator must also consider the composition of the OSP and how the chemistry performs with mixed-metal finishes. This includes OSP interaction with the SENIG (especially the exposed gold). An example of gold discoloration is shown in Figure 4. There is a side-by-side comparison of two commercially available OSP processes. One OSP is clearly not compatible with gold and should not be used in mixed-metal finish PCBs (OSP 1). These mixed-metal finish boards are becoming very common today and the surface treatment of such circuits will continue to grow in importance. The demand was such that a water soluble surface-treating agent, that was capable of protecting the bare copper from oxidation without leaving a film on the other metals, needed to be developed and implemented. In other words, the need for an OSP that selectively bonds to the copper without adversely affecting other metals such as gold or solder is critical for use in selective applications.

Conventional OSP technology deposits a significant film on the other metals such as

gold, tin and solder. This additional film interfered with subsequent operations such as wire bonding, and surface mounting of critical components. In addition, the contact resistance on the gold increased to unacceptable levels. Thus, when PWBs are fabricated with multiple metal finishes, the metals such as gold or solder would have to be masked to prevent the OSP film formation on their surfaces. In some instances, the coating would have to be removed with alcohol, adding additional labor and cost to the fabrication process. A factor in promoting this film formation on the metal surfaces in the copper contained in many organic solderability formulations. The copper ions form a complex with the active azole ingredient in the OSP chemistry and actually help to promote film growth. When a copper-gold mixed-metal board undergoes such a process, the OSP forms on the gold and will discolor the finish.

On the contrary, the OSP process for mixed-metal finishes do not contain copper ions to promote organic film growth. However, what happens if there are copper ions that are in solution simply due to exposure of the copper cir-

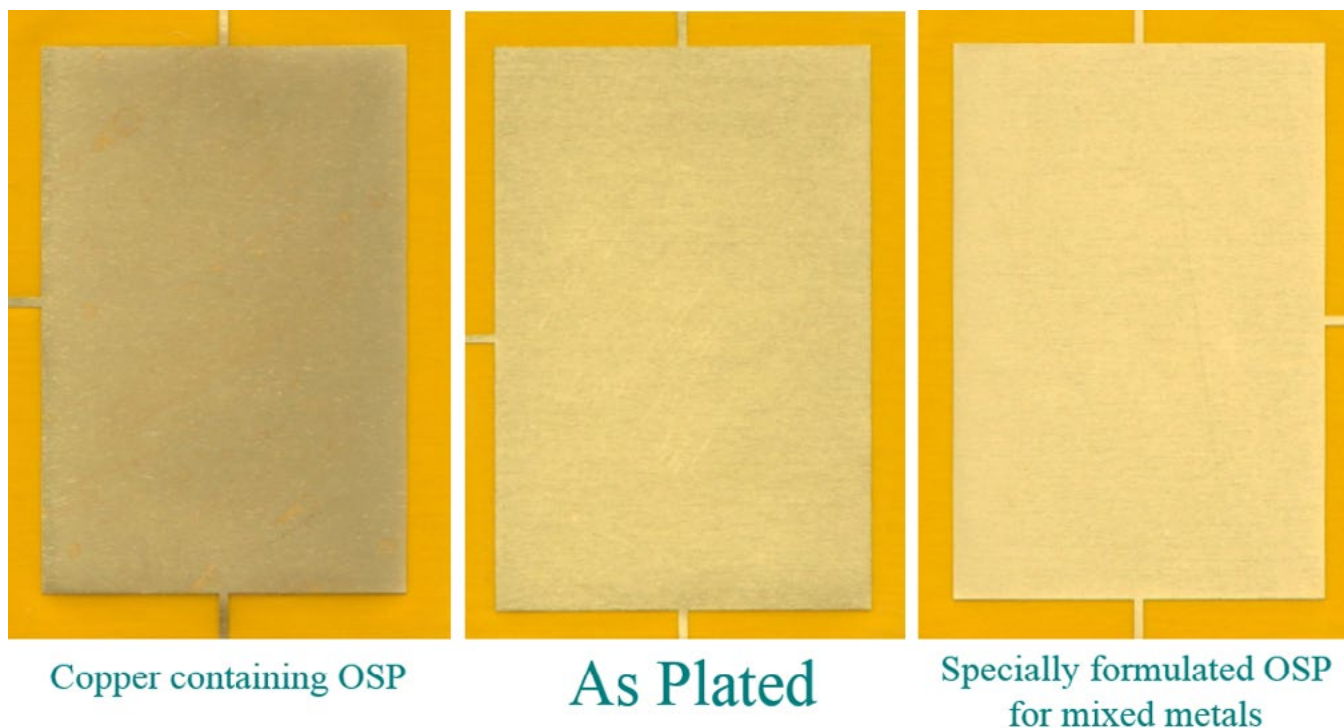
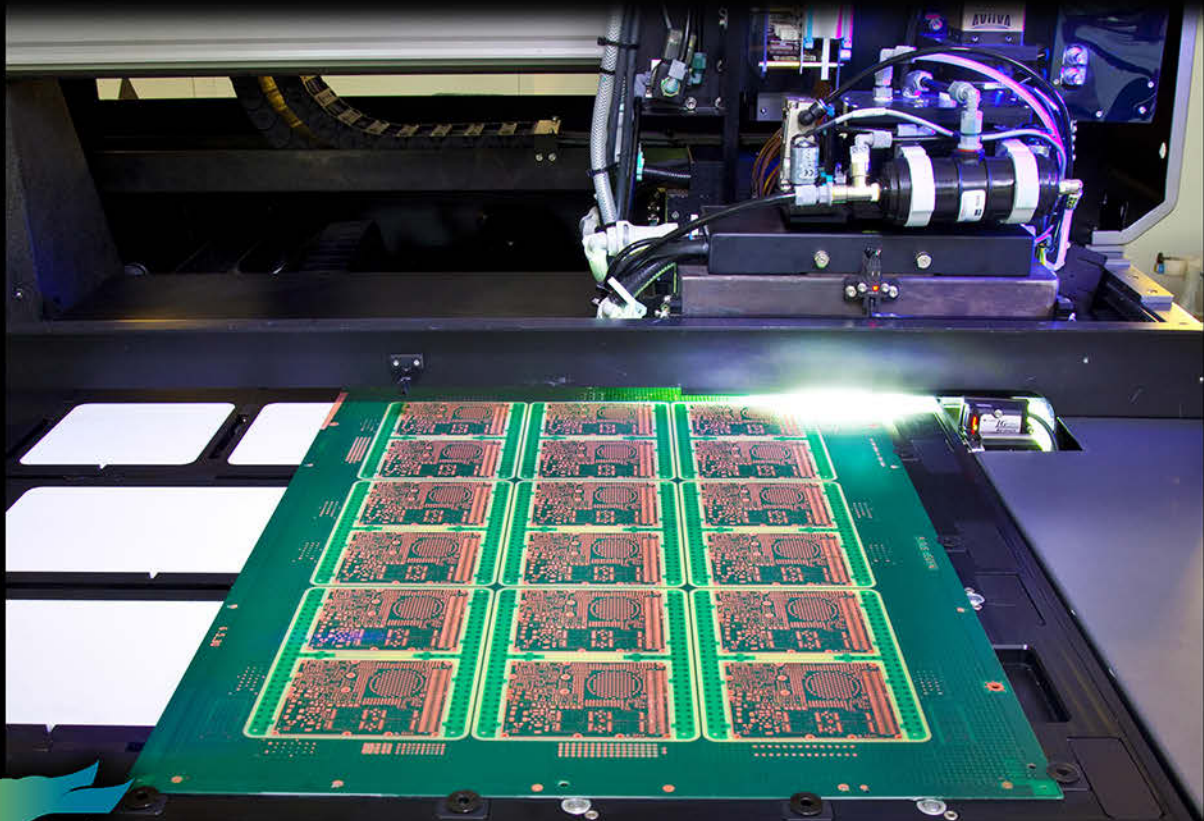


Figure 4: Comparison of conventional OSP versus mixed-metal finish OSP.

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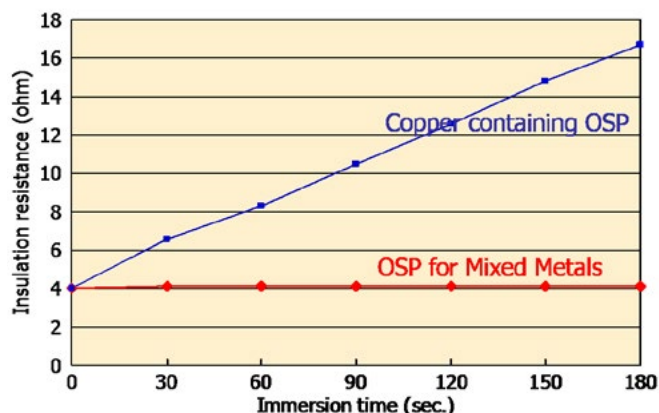
OSP AND SELECTIVE ELECTROLESS NICKEL *continues*

Figure 5: Insulation resistance on gold when copper containing OSP is compared to mixed-metal compatible OSP.

cuity to the OSP solution? Certainly these free Cu^{2+} ions would then be able to complex with the imidazole (OSP active ingredient) and form an organic film on the gold. The mixed metal compatible OSP additives complex these copper ions as they are formed in the OSP solution. Thus, this action prevents formation of the imidazole-copper ion complex that would deposit on the gold or other metal finish. However, this action does not interfere with the nitrogen functional group of the imidazole from forming an organic film on the copper. When OSP does coat the gold, there are adverse effects on insulation resistance (Figure 5).

The Galvanic Effect

The use of mixed metal finishes introduces another potential pitfall in fabrication. This is

commonly known as galvanic corrosion or the galvanic effect (Figure 6). Galvanic corrosion/degradation of dissimilar metallic surfaces in contact with each other is a well-recognized phenomenon. There exists a substantial body of work that has helped the electronics industry with understanding galvanic corrosion. Fontana and Greene^[1] classified galvanic corrosion as one of eight forms of corrosion. The Department of Defense issued a military handbook, MIL-HDBK-729 "Corrosion and Corrosion Prevention Metals", in an effort to provide basic, fundamental information on corrosion and corrosion prevention^[2]. The galvanic effect arises when two dissimilar metals are in contact with one another (such as nickel and copper with selective ENIG processing-basically copper-nickel gold interface). The issue is exacerbated by the type of micro-etch used. In addition, internal testing has shown that feature size particularly large area gold pads directly connected to copper traces leads to excessive etching of the copper at the interface. One may state that this is similar to a battery cell.

When two metals (gold and copper) are in contact with each other and in an electrolyte (micro-etch), a strong potential exists between the two metals. With such a strong potential existing in this scenario, it is very likely that aggressive copper removal will be the result (where the copper meets the gold). An actual example of the galvanic etch is shown in Figure 7.

It is quite evident that the gold plated trace makes intimate contact with the bare copper prior to OSP process. The aggressive etching that is taking place at the gold-copper junction

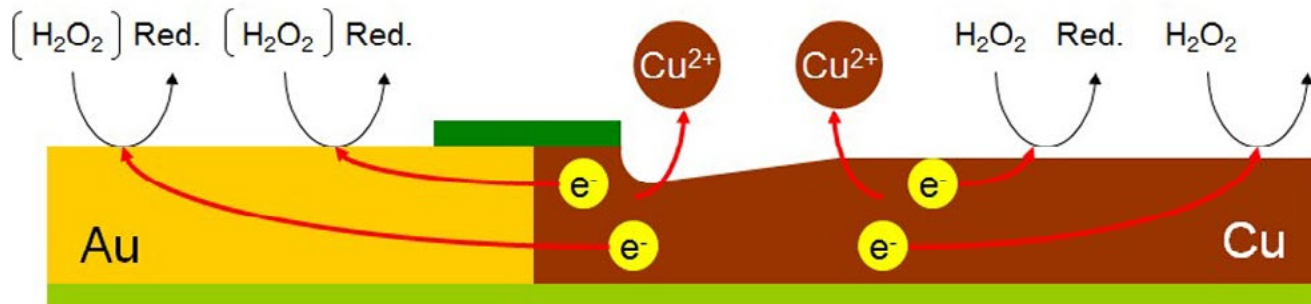


Figure 6: Schematic of galvanic etch mechanism.

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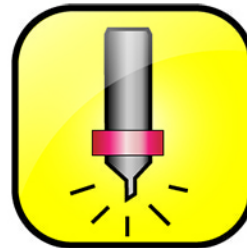
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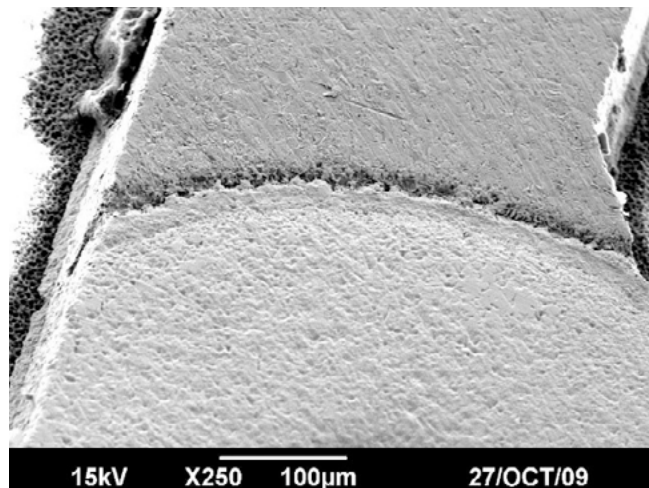
OSP AND SELECTIVE ELECTROLESS NICKEL *continues*

Figure 7: Example of galvanic etch with mixed-metal finish PCB (left) and close-up view of actual corrosion area known as the “trench” (right).

tion is quite evident. Further evaluation of the etched area shows a trench at the copper gold junction. Research suggests that the type of micro-etch plays a significant role in the galvanic cell formation. As an example, the oxidation redox potential of sodium persulphate in an aqueous medium is:



The oxidation potential of hydrogen peroxide in an aqueous acidic medium is approximately 1.7 V. Thus the persulphate anion is a much stronger oxidizer and provides a much stronger potential with which to effect the galvanic cell potential.

In addition to the type of micro-etching chemistry, the galvanic potential is affected by the ratio of the area of the anode to cathode. A rule of thumb (assuming design rules permit) in minimizing the galvanic coupling of metals is keeping the surface area ratio of the anode to cathode as large as possible. The large anode surface area (i.e., the corroding surface) results in a much smaller driving potential. However as shown in Figure 8, the gold circuit feature surface area is significantly larger than copper, resulting in a greater potential. Copper is the corroding surface. In each case the hydrogen peroxide sulfuric acid micro-etch gave more favorable results than the persulphate based

Appearance comparison for various micro-etchant on Galvanic-effect

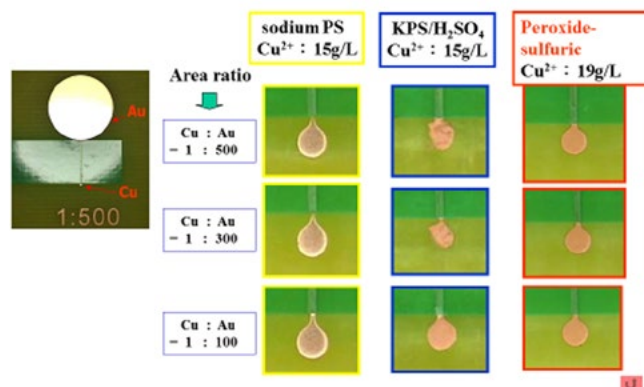


Figure 8: Comparison of three different micro-etches with three different anode to cathode areas.

etchants. This is explained by the fact that hydrogen peroxide sulfuric acid etchant have a lower potential than persulphate.

Lessons Learned with Mixed-Metal Finish Designs

First and foremost, select the EN process that will provide the best corrosion resistance under the various processing conditions. However, one should not default to a high phosphorous content system without first qualifying the process for solderability and reliability.

Placing additional emphasis on pH control of the nickel solution will help control the phos content. Excessively high phos content in the EN deposit (10.2–11.5%) will be detrimental to solderability as the action of the flux is diminished. Secondly, higher phos content EN deposits will act to minimize the immersion gold thickness.

With respect to OSP, there are a number of challenges. First, don't force the OSP process to deposit more than 2500–3500 angstroms in thickness (0.25–0.35 micron). Excessive OSP film thickness could lead to organic deposits on the gold.

In addition, judicious selection of an OSP chemistry devoid of copper ions will minimize staining of the gold in mixed metal finish designs. Some folks are of the opinion that a thicker OSP coating on the copper provides more oxidation protection (read, better solderability) than thinner coatings. The data does not support such an assertion. Thinner OSP coatings perform quite effectively under lead-free soldering conditions as long as the OSP itself is able to reduce oxygen penetration to the base metal copper (Figure 9). This has been substantiated in publications^[3]. The amount of copper oxidation (Cu_2O) was compared by the peak height at certain wavelengths (approx. 640 cm^{-1}) with FT-IR as shown in Figure 9. Longer heat treatment times will accelerate the oxidation of copper. Thicker coatings tend to minimize the oxidation as shown in Figure 9. However, OSP-A, newly designed for BGA substrate applications minimizes the copper oxidation significantly in comparison with OSP-B and C. This result leads to better solder ball spreadability as well as higher solder joint strength afterward^[3].

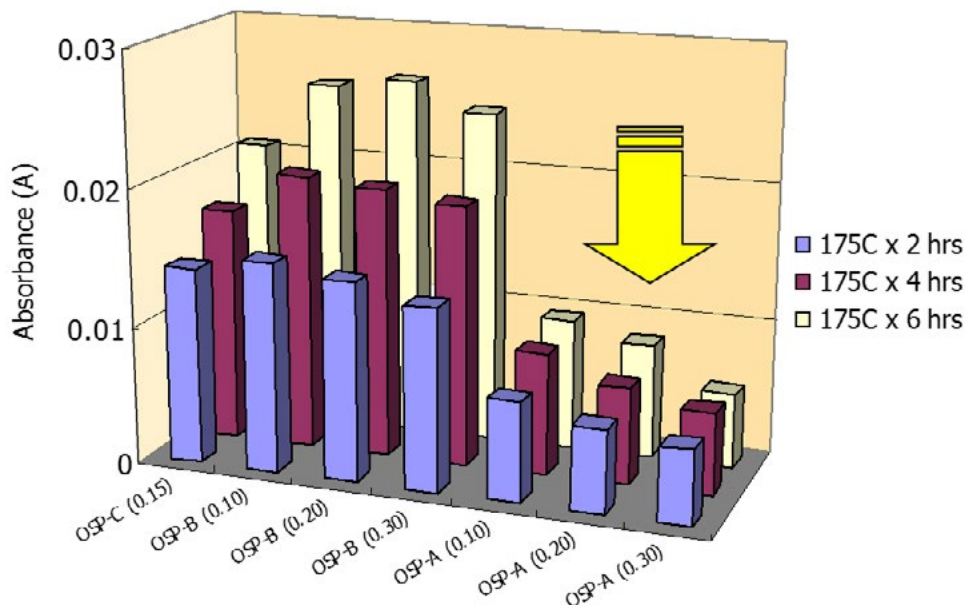


Figure 9: Oxygen penetration of OSP coated copper surface. Comparison of three commercially available OSP chemistries.

While thickness of the overall organic film is important (to an extent), the OSP's ability to resist or minimize oxidation of the underlying is much more critical when subjected to heat cycles.

Furthermore, the fabricator should use a micro-etch that has a lower redox potential as this will provide some protection of the galvanic cell. **PCB**

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3. M. Carano and K. Saeki, IPC Components Conference, September, 2013.



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](#).



HASLEN: A New High-Reliability Surface Finish for PCBs

**by Prof. Karl Ryder and
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MATERIALS CENTRE, UNIVERSITY OF LEICESTER
Dennis Price, MERLIN PCB
Tom Perrett, QUALITEK (EUROPE)

In this article, we will detail hot air solder levelled electroless nickel (HASLEN), a new PCB surface which removes the necessity to coat the nickel with gold, yielding substantial cost benefits while removing the step in which black pad can form. The end result is improved reliability to both solder wetting and the resulting solder joint, and greatly extending the shelf life of the PCB.

This surface finish has been developed by the University of Leicester in conjunction with Merlin PCB and Qualitek (Europe).

Introduction

Surface protection of copper-tracked PCBs is essential for ensuring consistent solderability during the electronics manufacturing process. This is due to the continued oxidation of copper into copper oxide on the surface of the PCB,

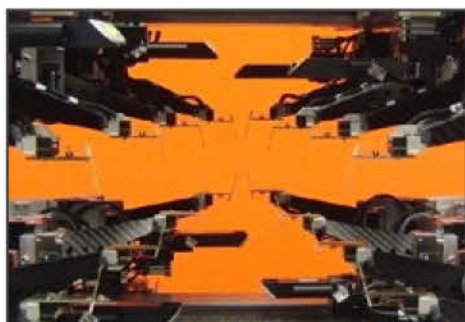
which is difficult to remove and can prevent the formation of a uniform solder joint after reflow. The majority of PCB surface finishes involve coating the copper with a metal or organic compound such as solder by hot air solder levelling (HASL), silver, tin or an organic soldering preservative (OSP).

High-reliability, high-value surface finishes often have an additional electroless nickel layer such as electroless nickel immersion gold (ENIG). Where electroless nickel coatings are used, they always have to be coated with an additional layer of an inert metal such as gold or palladium, which serves to maintain solderability for an increased period of time. This is because nickel readily forms a passive oxide layer on its surface that is very difficult to remove. As a consequence, during soldering, no solder fluxes are able to remove this oxide layer, preventing the electroless nickel underneath from coming into contact with the molten solder. This is an environment in which it is very difficult for a uniform a solder joint to form. The deposition of a thin layer of gold prevents the nickel oxide from forming and the surface remains highly solderable.

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HASLEN: A NEW HIGH-RELIABILITY SURFACE FINISH FOR PCBs *continues***DES Solder Fluxes**

At the University of Leicester a new type of solder flux has been developed based on a novel class of liquid called deep eutectic solvents (DES). These liquids are composed of organic salts and small, polar organic molecules called “hydrogen bond donors”. Because of the unique chemical makeup of these liquids they act as a highly coordinating environment for metal salts. It has been demonstrated that, even at relatively moderate temperatures, they have good solubility of metal oxides.^[1, 2]

The high metal salt solubility means that DES act as highly active solder fluxes for a wide variety of metal substrates. At the higher temperatures at which soldering takes place (typically above 200°C) they can rapidly remove the oxide from a surface of a metal substrate enabling solder joint formation^[3]. Figure 1(a) shows a solder wetting balance trace for oxidised copper wire coated with a DES flux and immersed to a depth of 5 mm into a SAC 305 solder bath at 260°C. This is then compared to an example wetting trace for the standard flux Actiec5 under the same conditions. Actiec5 is a rosin flux with added organic acids to improve solderability and is generally regarded as a highly active flux in the electronics and PCB industries. For all wetting traces a buoyancy response is seen as the copper wire is dipped into the solder pot. Where a DES flux was used a very

rapid increase in the force is seen as the copper oxide is removed from the copper surface and a solder joint starts to form. This is in contrast to Actiec5 which, while still wetting the surface of the copper, takes a much longer time to do so suggesting that the DES flux is much more active than Actiec5.

As mentioned prior, the high activity of these DES solder fluxes means that they can be used to solder a wide variety of metallic surfaces including all common PCB surface finishes: brass, nickel, mild steel, stainless steel and cast iron. Remarkably, they can also be used to solder electroless nickel as shown by the solder wetting trace in Figure 1(b) where an electroless nickel surface was coated with a DES flux and immersed in SAC 305. The response is very similar to that seen for copper wire, where after an initial buoyancy force is overcome the force increases rapidly as the oxide is removed from the surface and the electroless nickel substrate can interact with the molten solder.

The ability to solder electroless nickel is important for two areas within the PCB industry:

- 1) The potential to sell electroless Ni PCBs, or indeed bare copper PCBs, without any additional protective layer, to end users, and
- 2) HASL coating of electroless nickel using DES fluxes.

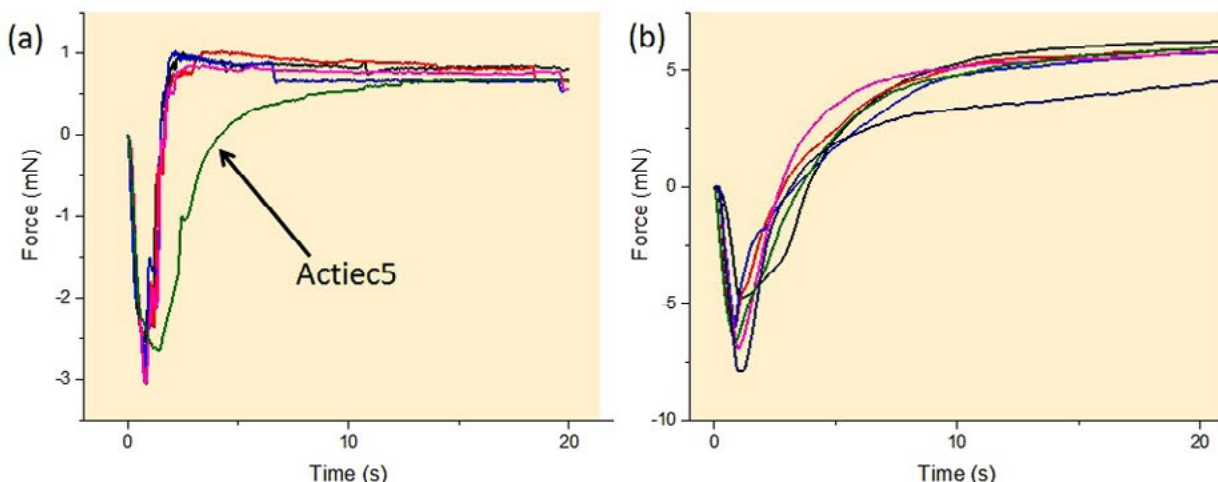


Figure 1: Repeated solder wetting balance measurements using a DES flux on (a) copper wire and (b) electroless nickel coated copper sheet with SAC 305 solder.

HASLEN: A NEW HIGH-RELIABILITY SURFACE FINISH FOR PCBs *continues***The HASL Surface Finish**

This article will deal with the second point, HASL coatings onto electroless nickel surfaces. HASL is probably the oldest PCB surface finish that is still available today. This involves taking a fluxed copper track PCB panel and dipping it into a pot of molten solder for a short period of time as shown in Figure 2(a). Upon removal hot air knives on either side of the PCB panel blow off the excess solder. The result is that the exposed copper is covered in a thin layer of solder ranging from 3 to 15 μm depending on the surface area and orientation of the PCB panel. An example of a HASL soldered PCB panel is shown in Figure 2(b). The HASL surface finish is recognized for being highly solderable, as the surface is normally very similar in composition to that of the solder being used. An example image of the cross-section is shown in Figure 4(a) where a thin 1–2 μm intermetallic layer has formed between the solder and the copper substrate.

A New Technology From Existing Processes

The HASLEN surface finish follows the same process, with the exception that a PCB panel that is coated in electroless nickel is used rather than copper. It is the unique solvation environment provided by these DES fluxes that enables the oxide removal from electroless nickel, meaning that this process is possible.

The structure of a HASLEN finished PCB is demonstrated in Figure 3(a) where the copper has a 6–7 μm layer of electroless Ni that is used as standard in ENIG PCBs followed by a layer of solder that ranges from 3–15 μm in thickness. As the method of removal of the excess solder in HASL is physical (i.e., by air knives) there is a thickness variation dependent on the size of the pad as well as orientation. Figure 3(b) shows an image of a PCB that has been prepared with a HASLEN coating. The surface pads show uniform coverage right across their whole surface area and in addition both vias and plated through holes are coated right through the whole thickness of the PCB.

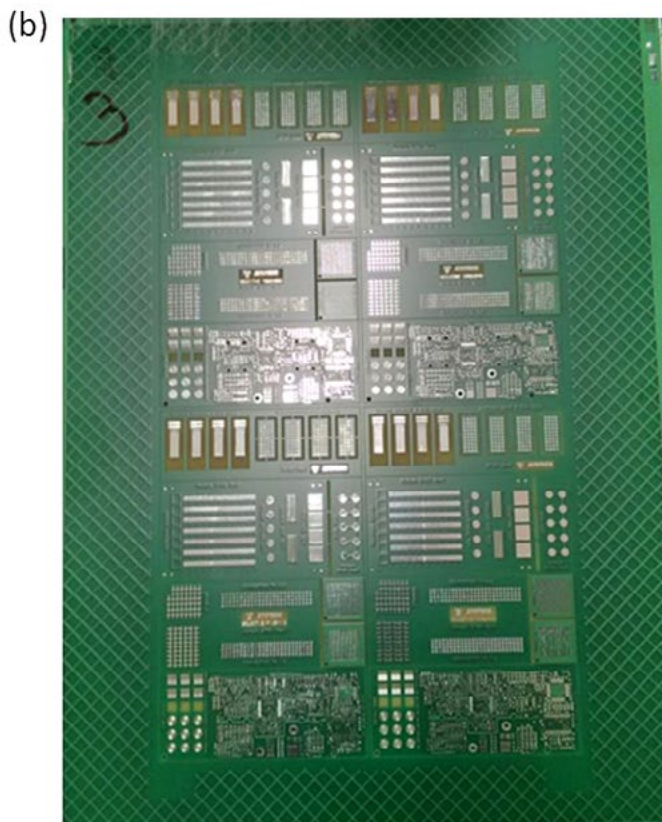
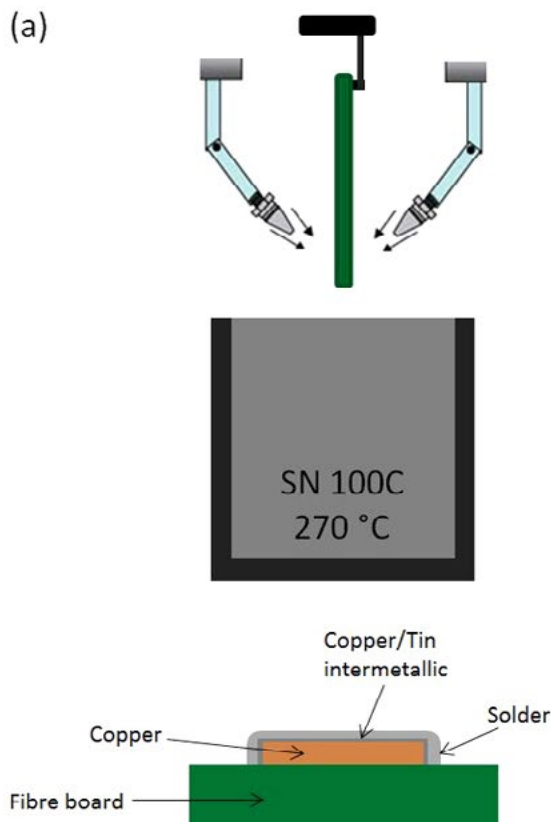


Figure 2: (a) Diagram of HASL coating setup and (b) image of HASL coated PCB panel.

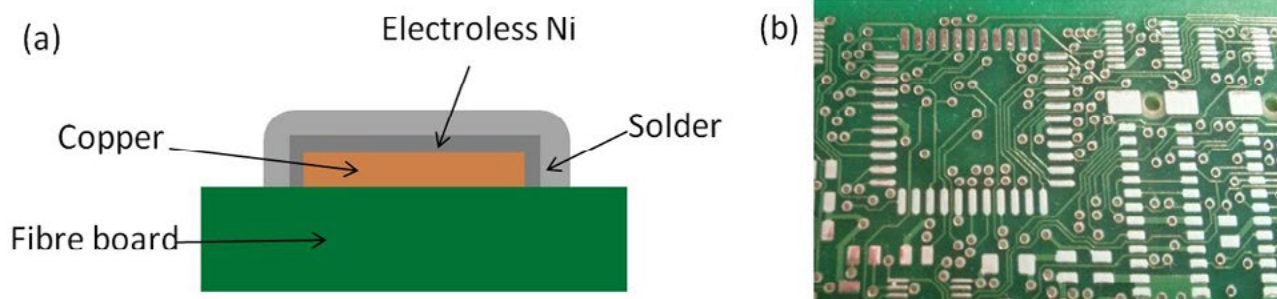
HASLEN: A NEW HIGH-RELIABILITY SURFACE FINISH FOR PCBS *continues*

Figure 3: (a) Cross-sectional diagram of a HASLEN coating and (b) image of the resulting HASLEN surface finish.

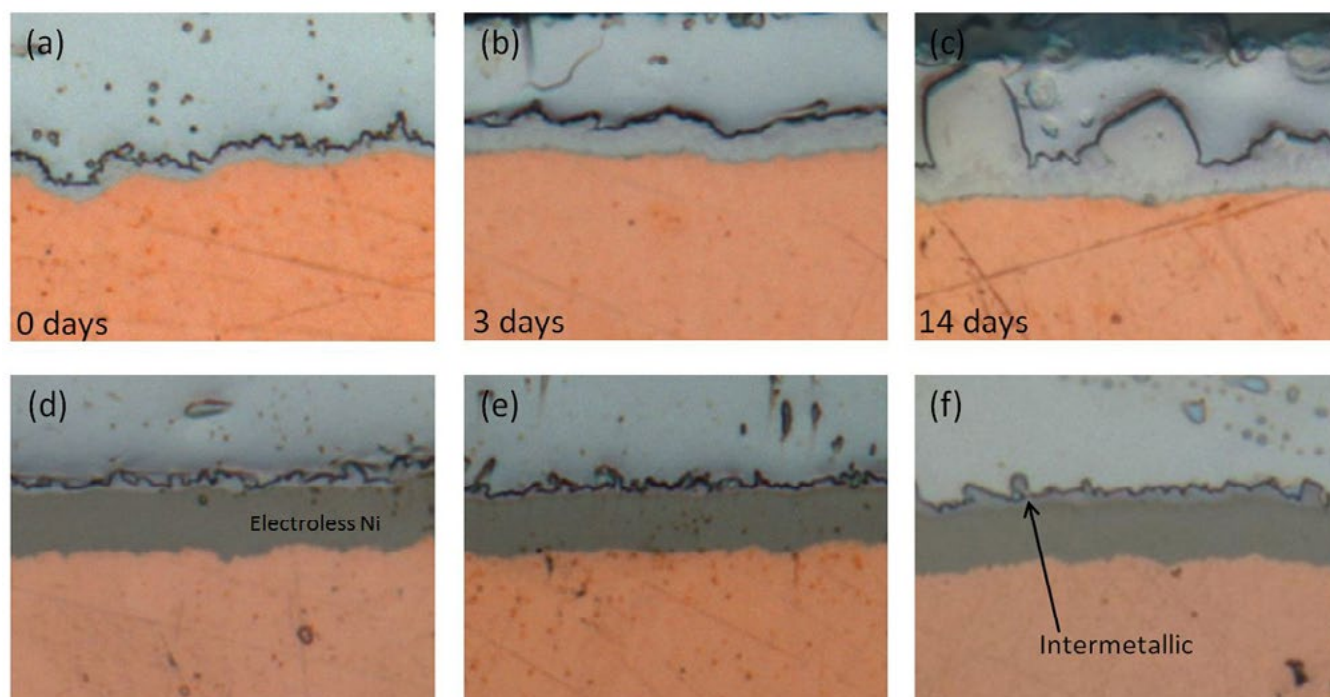


Figure 4: Cross-sectional images of HASL (a, b and c) and HASLEN (d, e and f) that have been in an oven at 130°C for 0, 3 or 14 days.

Figure 4(d) shows a cross-section of a HASLEN coated PCB where a thin electroless nickel layer can be seen above the copper, visible as a dark grey band. Above this is the solder, visible as the light grey metal. As with all conventional HASL PCBs there is an intermetallic layer formed but in this case the intermetallic layer is formed between the solder and electroless nickel rather than the copper. This has important considerations for PCB longevity and use as the rate of intermetallic growth for and electroless nickel

solder joint is much lower than that of a copper solder joint.

Improved Lifetime and Reliability vs. HASL

The differing nature of the intermetallic growth between HASL and HASLEN solder joints is highlighted through accelerated aging studies as shown in Figure 4. Conventional HASL and HASLEN PCBs were placed in an oven at 130°C for varying periods of time, cross-sectioned and imaged under a microscope.

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Figures 4 (a, b & c) show the cross-sections of HASL PCBs after 0, 3 and 14 days, respectively. As discussed previously, a small intermetallic layer is formed between the copper and solder during HASL coating. However, this has grown considerably from 1–2 μm thickness to approximately 2–3 μm thickness after 3 days. After 14 days the intermetallic has continued to grow even thicker, however, rather than growing uniformly throughout the sample, intermetallic growth is localised to specific areas, in some cases growing through to the surface of the solder.

The considerable and non-uniform intermetallic growth in HASL PCBs and their resulting solder joints is detrimental to the use of the PCBs for a number of reasons:

1) The shelf life of the PCB is reduced. Intermetallics are much more difficult to solder than either copper or solder, and intermetallic growth through to the surface of the PCB panel will create unsolderable regions. This reduces the shelf life of the PCB.

2) The solder joints are more susceptible to brittle fracture, particularly when they are used at high temperatures. Copper/tin intermetallics are more brittle than either tin or copper and as a result solder joints with thick intermetallic layers are more likely to undergo brittle fracture causing failure of the solder joint.

3) Thick, non-uniform intermetallic regions are linked to tin whisker growth. It is believed that stress within the solder joint created by the intermetallic growth causes tin whisker growth. Tin whiskers can be catastrophic to the working of a PCB or electronic because of the ability for the whiskers to cause short circuits.

In contrast, Figures 4 (d, e & f) show the cross-sections of a HASLEN PCB after 0, 3 and 14 days, respectively. Initially, a thin intermetallic layer is formed during the HASLEN process. However, very little (if any) intermetallic growth is seen as the coupons have undergone accelerated ageing and all of the images appear very consistent in their structure.

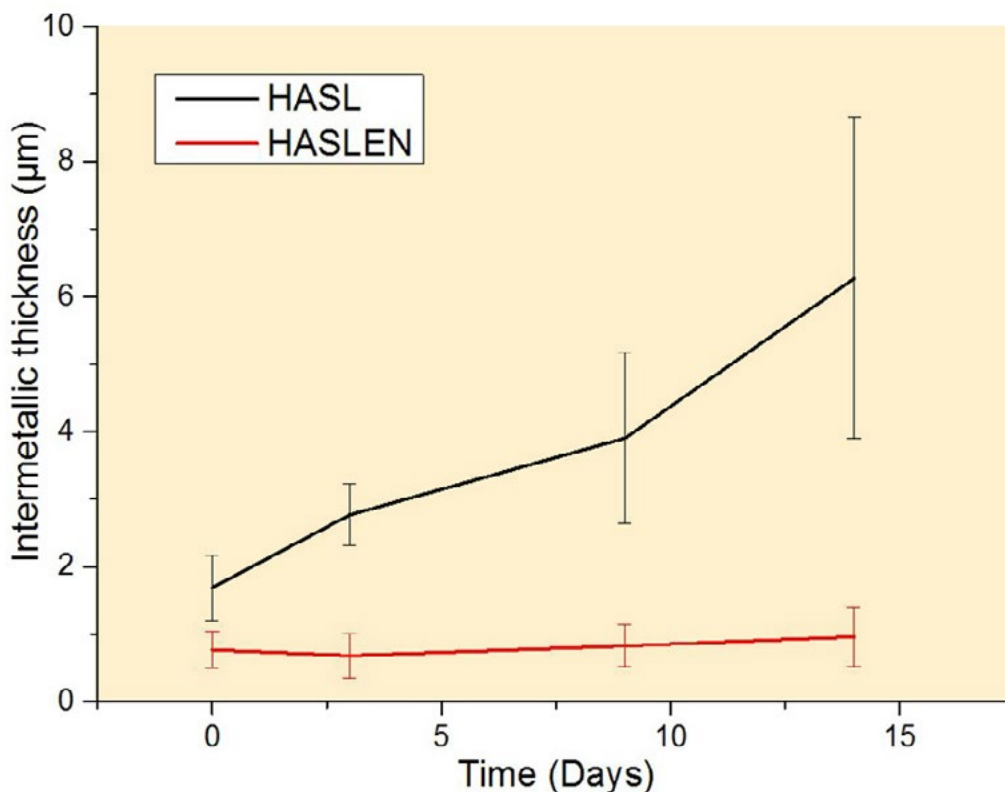


Figure 5: Intermetallic thickness of HASL and HASLEN coatings undergoing accelerated aging at 130°C.

HASLEN: A NEW HIGH-RELIABILITY SURFACE FINISH FOR PCBs *continues*

This is highlighted further through Figure 5, where the average thickness and standard deviation of the intermetallic layer has been measured from the microscope images. The HASL intermetallic layer grows rapidly at approximately 2 $\mu\text{m}/\text{week}$, with considerable height variation due to the formation of the larger nodules.

In contrast, the thickness of the HASLEN intermetallic layer has barely changed, showing very little alteration in the composition through the coating. This has very exciting implications to the properties of a HASLEN PCB compared to one that is HASL coated:

1) The PCBs should in theory have an almost infinite shelf life as it would take an extremely long time for any intermetallic growth to make its way through to the surface of the pad.

2) As intermetallic growth is very slow then any resulting solder joint should be less susceptible to brittle fracture causing a more reliable electronic after manufacture. This is particularly true where HASL PCBs are used in high temperature situations.

3) The electroless Ni layer should help to mitigate tin whisker formation. Because the intermetallic layer is thin and uniform then stresses within the coating should be lower reducing the likelihood that tin whiskers will form.

The results above demonstrate the improved behaviour of PCBs with an electroless nickel barrier layer versus conventional HASL, or in fact any other surface finish which consists of a thin layer of a protective metal directly onto copper such as immersion tin, immersion silver and OSP as once soldered the nature of the solder joint should be similar for all of these surface protection methods. This additional benefit of having an electroless nickel barrier layer should be consistent for HASLEN, ENIG and any other protective surface finish in which such a barrier layer is present.

ENIG and Black Pad

Due to the presence of gold in the surface finish, ENIG presents considerable

cost implications and often is only used where absolutely necessary or for examples where high reliability is key. However, ENIG also possesses its own challenges and reliability problems, the most common of which is referred to as black pad.

The ENIG surface finish is a combination of two processes to provide a coating system with two distinct layers. First, a Ni layer is deposited followed by a thin immersion gold layer to prevent passivation of the underlying nickel substrate.

With an immersion process, a metal on a surface is exchanged for one which is more "noble" from solution. In this case, nickel on the surface is oxidised into solution with gold being reduced onto the surface. As such, this is an inherently corrosive process which, in addition to the immersion gold bath being necessarily acidic to prevent the nickel layer from passivation, can lead to corrosion problems. An example of this is shown in Figure 6 where excessive reaction has occurred down an electroless nickel grain boundary. In areas where excessive reaction has occurred, the Ni surface becomes oxidised, meaning that it is rendered

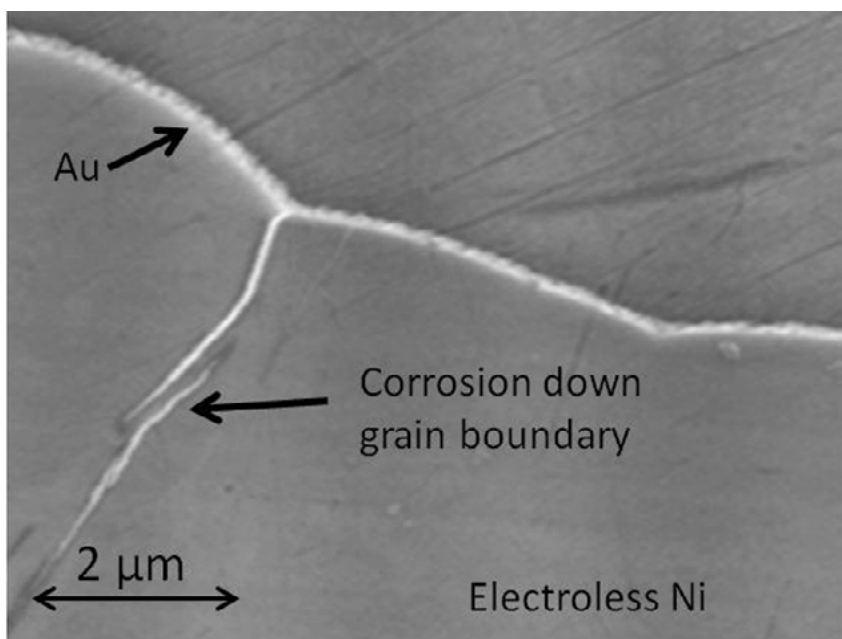


Figure 6: Cross-section of an ENIG-coated PCB showing attack down electroless Ni grain boundary during immersion gold deposition.

HASLEN: A NEW HIGH-RELIABILITY SURFACE FINISH FOR PCBs *continues*

unsolderable using current solder fluxes. When this happens, there is often still full coverage of gold across the surface, making it extremely difficult to tell non-destructively whether there is a problem with the coating.

In addition to the surface of the PCB appearing to have a good finish, once the PCB has gone through an assembly process, the solder joint appears to have formed correctly but is in fact very weak and is thus likely to fail quickly when used as a product.

HASLEN, while possessing the benefits of having an electroless nickel barrier to the underlying copper, does not require the corrosive immersion gold layer and as such the process responsible for black pad has been removed. As a consequence, PCBs with the HASLEN surface should be more reliable than their ENIG coated counterparts.

Conclusions

We have detailed the new surface finish HASLEN. This is a process that combines electroless nickel coating of PCBs with hot air solder levelling, very common processes used by most PCB manufacturers in the world. Solder levelling of electroless nickel is very difficult as very few solder fluxes are capable of removing the oxide layer from electroless nickel. This has been enabled by solder fluxes based on the novel liquids' deep eutectic solvents.

HASLEN provides a surface finish which has a higher shelf life than conventional HASL, should produce more reliable electronics post assembly, particularly when used in high temperature environments, and additionally, reduce tin whisker formation. When compared to ENIG it provides many of the same functionalities while not requiring the costly immersion gold process. The gold deposition process is linked to black pad, the source of a major reliability problem with ENIG PCBs. HASLEN offers an alternative coating method to provide a solder joint with the same properties as that of ENIG but with significantly less reliability problems.

Acknowledgements

This coating technology has been developed in conjunction with Merlin PCB and Qualitek

(Europe) and special thanks go to both Dennis Price and Tom Perrett for their ongoing help and guidance with its development. Additionally, thanks go to IeMRC for funding.

For more information on this new technology, please visit www.haslen.org. To obtain a sample HASLEN coated PCB, please contact [Andrew Ballantyne](#), [Dennis Price](#), or [Tom Perret](#). **PCB**

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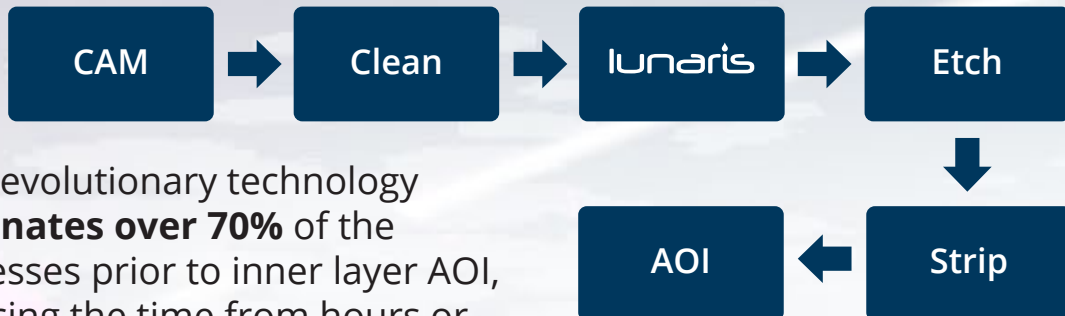


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According to market intelligence firm ABI Research, the average weeks of household income needed to buy a tablet or Ultrabook both declined by approximately 30% YoY, making these devices more affordable to a wider range of consumers.

Satellite Communications Market to Generate \$3.1B by 2023

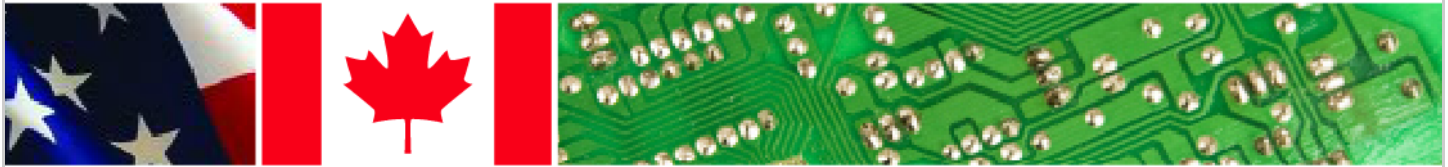
NSR's newly released Unmanned Aircraft Systems (UAS) via Satellite report projects impressive growth for satellite-based UAS in all regions, with revenues rising from \$1.3 billion in 2013 to \$3.1 billion in 2023.

Investment in Microgrid-enabling Tech Tops \$155B

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IPC Plating Sub-committee 4-14: Surface Finish Specifications

by **George Milad**

UYEMURA

CO-CHAIR, IPC PLATING SUB-COMMITTEE 4-14

IPC specifications are reference documents called out by designers and OEMs. Designers may take exception with one or more items in the specification to ensure that the product meets the requirements of its intended use. The acronym AAUBUS (as agreed upon between user and supplier) is part of any specification.

Specifications are consensus documents. They are agreed upon by a panel of interested industry participants composed of suppliers, manufacturers, assembly houses (CMs) and end users. The IPC Plating Sub-committee 4-14 is no exception.

When there is consensus, the committee documents it in a specification. In cases where no consensus is readily arrived at, the committee undergoes its own testing in what is commonly referred to as a round-robin (RR) study. In a RR investigation, an agreed upon test vehicle (TV) is designed and manufactured. TVs are then sent around to the different suppliers who deposit the agreed upon thicknesses to be investigated. The TVs are collected and the deposit thicknesses are verified and documented. The TVs are then coded. The TVs are sent around again to the different testing sites that test for the desired attribute like soldering, contacting and wire bonding capabilities of different finish

thicknesses. The data is then collected, sorted out and documented. At this point, a new attempt at consensus is made and upon arrival, the thickness specification is set.

A draft is prepared after consensus is complete. The draft is then posted for peer review. Any IPC member can review the document and suggest technical or editorial changes. All comments are then reviewed and all issues resolved before the final draft is issued. At this time the IPC takes on the task of publishing the document in its final format.

The IPC Plating Sub-committee 4-14 has been active since 2001. It is co-chaired by me and Gerard O'Brien of ST and S Group. The IPC liaison is Tom Newton. The sub-committee has an extensive member list composed of OEMs, contract assemblers, board manufacturers, chemical suppliers, as well as labs and consultants.



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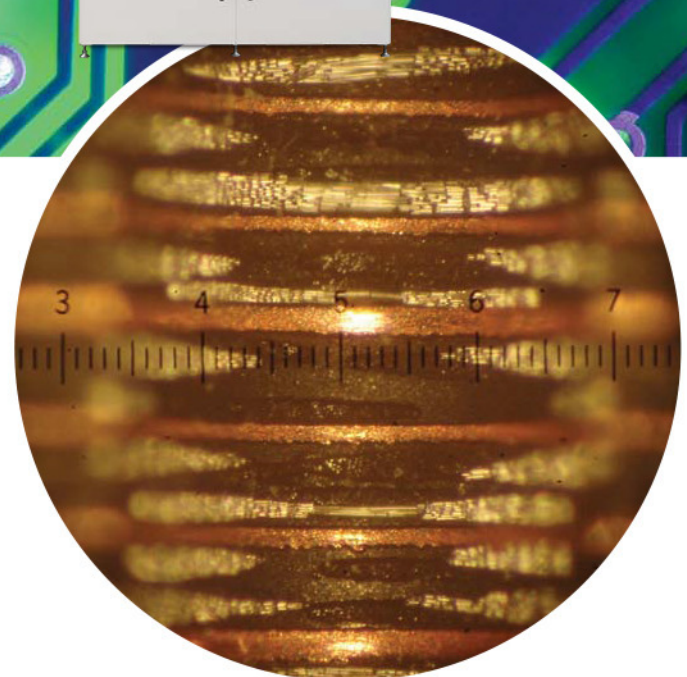
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IPC PLATING SUB-COMMITTEE 4-14: SURFACE FINISH SPECIFICATIONS *continues*

The committee operates through one-hour, bi-weekly conference calls. Calls are held every other Wednesday at 11:00 a.m. EST, and everyone is welcome to participate. A notification e-mail is sent out before each conference call. All decisions pertaining to initiation and follow up on round-robin studies, evaluation of results, draft review, etc., are made during these calls, by those in attendance. The call minutes are documented and circulated.

Since its inception, the IPC Plating Subcommittee 4-14 has issued the following:

- IPC-4552 ENIG Specification 2002
- IPC-4553 Immersion Silver specification 2005
- IPC-4554 Immersion Tin Specification 2007
- IPC-4553A Revised Immersion Silver 2009
- IPC-4554 Amended Tin Specification 2011
- IPC-4552 Amended ENIG Specification 2012
- IPC-4556 ENEPIG Specification 2013

Following is a discussion of each of the above:

Electroless Nickel/Immersion Gold (ENIG) IPC-4552, 2002

ENIG is a coplanar surface finish composed of a nickel layer capped with a thin layer of gold. The ENIG surface finish is solderable, aluminum wire bondable, and an excellent contacting surface, with a minimum shelf life of 12 months under standard storage conditions. The immersion gold layer protects the underlying nickel from oxidation/passivation over its intended shelf life. Thickness specifications are set to ensure the ability of the finish to meet the above criteria.

The ENIG IPC-4552 Specification was issued in 2002, and at the time of setting the specification for ENIG, no lead-free (LF) solder was in use. For thickness, IPC-4552 stated:

• The EN thickness shall be 3–6 μm [118.1 to 236.2 μin] The IG minimum thickness shall be 0.05 [1.97 μin], at four sigma (standard deviation) below the mean; typical values for IG of 0.075 to 0.125 μm [2.955 to 4.925 μin]

Although no upper limit was set, the specification had a statement for suggested typical values for IG of 0.075 to 0.125 μm [2.955 to 4.925 μin]. These values were erroneously interpreted to be the specification.

The ENIG specification was amended in 2012:

• The lower limit for thickness was reduced from 0.05 μm to 0.04 μm (1.6 μin) with the following restrictions:

- Limited time from manufacturing to assembly
- Demonstrate the consistency of the plating process
- Ability to measure low gold thickness

Presently, the ENIG 4552 is in revision and should be out in 2015 (Revision A). The objective of the revision is to set new lower and upper thickness limits for the immersion gold, to determine if the restrictions in the amended ENIG spec could be lifted, to limit the typical pad size to be measured and to make the specification applicable to LF solder and LF conditioning. This entails an extensive RR study, presently in progress.

The intent is that the revised IPC-4552 Rev A would also include the following Additional Documents:

- Test method (TM) for stripping immersion gold during failure analysis
- Test method for determining the phosphorus content of electroless nickel
- A corrosion chart setting acceptability criteria for nickel corrosion (black pad)

Immersion Silver (IAG) IPC 4553 A, 2009

IAG is a thin, immersion silver deposit over copper. It is a multifunctional coplanar surface finish, applicable to soldering. It may also be applicable for some press-fit connections and as a contact surface. It has the potential to be suitable for aluminum wire bonding. The immersion silver protects the underlying copper from oxidation over its intended shelf life. Exposure to moisture and air contaminants, such as sulfur



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IPC PLATING SUB-COMMITTEE 4-14: SURFACE FINISH SPECIFICATIONS *continues*

and chlorine, may negatively impact the useful life of the deposit. The impact can range from a slight discoloration of the deposit to the pads turning completely black. Proper packaging is a requirement for achieving a 12-month shelf life.

The Immersion Silver IPC-4553 Specification

In 2005, there were two distinct types of commercialized immersion silver with different thickness recommendations, referred to by the committee as “thin” and “thick.” Each required its own thickness specification. This created much confusion as the terms were poorly defined.

The initial IPC-4553 Immersion Silver Specification specified two thicknesses and stated the following for thickness of deposit:

- *Thin Silver: 0.05 μm (2 μin) minimum at -2σ from process mean as measured on a pad of area 2.25² μm (3600² mils). Typical value 0.07 μm (3 μin) to 0.1 μm (5 μin)*
- *Thick Silver: 0.12 μm (5 μin) minimum at -4σ from process mean as measured on a pad of area 2.25² μm (3600² mils). Typical value of 0.2 μm (8 μin) to 0.3 μm (12 μin).*

In 2009, the immersion silver specification was revised. At this time the lower thickness supplier has discontinued his product and the industry was left with a common thickness from multiple suppliers. This revised specification only had one thickness specified (eliminating reference to thin and thick). The revised specification now includes an upper thickness limit. Typical values were recommended within the specified limits. The pad size for taking the thickness measurement was also specified.

The IPC-4553 Rev A Immersion Silver Specification stated the following for thickness of deposit:

- *The immersion silver thickness shall be 0.12 μin [5 μin] minimum to 0.4 μm [16 μin] maximum at $\pm 4\sigma$ from process mean. Typical value between 0.2 μm [8 μin] to 0.3 μm [12 μin] as measured on a pad of area 2.25 mm² or 1.5 mm X 1.5 mm [approximately 0.0036 in² or 0.060 in X 0.060 in] or equivalent.*

Immersion Tin (ISn)

IPC- 4554, 2007; amended 2012

The immersion tin (ISn) is a metallic finish deposited by a chemical displacement reaction that is applied directly to the basis metal of the printed board, which is copper. The immersion tin is primarily used as a solderable surface for attachment of components. It may also be used when press-fit connections are employed and for zero insertion force (ZIF) edge connectors. The immersion tin finish protects the underlying copper from oxidation over the intended shelf life (storage of greater than six months) of this finish.

Immersion Tin

IPC-4554 Specification

For immersion tin, the committee specified a lower limit for thickness. The relatively thick value of 1 micron (40 μin) was chosen to ensure that enough virgin tin would be available at the surface for soldering after extended storage. It is well understood that tin forms an intermetallic (IMC) layer with the underlying copper, and that this layer continues to grow in thickness over time.

The immersion tin thickness will be:

- *μm (40 μin) minimum at -4σ from process mean as measured on a pad of area 2.25² μm (3600² mils) or equivalent. Typical value of 1.15 μm (46 μin) to 1.3 μm (52 μin).*

The Immersion Tin Specification IPC-4554 was amended in 2011. The amendment addressed solderability testing and specified the allowed stress testing conditions for the deposit and the type of fluxes to be used for both tin/lead and LF testing.

Electroless Nickel/Electroless Palladium/ Immersion Gold (ENEPIG)

IPC- 4556, 2013

ENEPIG is a coplanar tertiary layered surface finish plated over copper as the basis metal. EN-EPIG consists of an electroless nickel base layer over which is plated an electroless palladium barrier layer followed by a deposit of a thin immersion gold as the final outer layer. It is a multifunctional surface finish, applicable to soldering and to gold, aluminum and copper wire bonding. It is also suitable as the mating surface

IPC PLATING SUB-COMMITTEE 4-14: SURFACE FINISH SPECIFICATIONS *continues*

for soft membrane and steel dome contacts. Additional applications include use in low insertion force (LIF) and zero insertion force (ZIF) edge connectors and for press-fit applications. The electroless palladium layer forms a diffusion barrier that impedes nickel diffusion to the gold surface. The immersion gold protects the palladium layer from reacting with contaminants prior to processing that might otherwise affect joining processes, such as wire bonding and soldering. ENEPIG has a minimum shelf life of 12 months under standard storage conditions. Thickness specifications are set to ensure the ability of the finish to meet all the attributed functionality.

The ENEPIG**IPC-4556 Specification**

This is the last specification issued by the committee. The document produced is very comprehensive and includes a wealth of information from the RR studies that were conducted.

The Appendix contains a documentation of these studies, each authored by the principle who conducted the testing. It also includes a section on the proper methods of equipment setup for a reliable measurement of very thin layers of metal deposits.

The thickness specification for ENEPIG states:

- **Nickel:** 3 to 6 μm [118.1 to 236.2 μin] at ± 4 sigma (standard deviations) from the mean.
- **Palladium:** 0.05 to 0.15 μm [2 to 12 μin] at ± 4 sigma (standard deviations) from the mean.
- **Gold:** minimum 0.025 μm [1.2 μin] at - 4 sigma (standard deviations) below the mean. No upper limit was set for IG.

All measurements to be taken on a nominal pad size of 1.5 mm x 1.5 mm [0.060 in x 0.060 in] or equivalent area.

Organic Solderability Preservative (OSP)**IPC Specification (NONE)**

OSPs are organic coatings that form a complex organo-metallic complex with the copper surface of the PWB. This complex preserves the solderability of the copper surface through assembly.

A wide variety of OSPs have evolved with the increasing complexity of the PWB. Initially, all that was required was a single thermal excursion for soldering leads into component holes. Then came surface mount that required at least two thermal excursions (one per side); add on top of that the need to hand solder an occasional rework. The biggest relevant evolution is lead-free assembly. LF assembly temperature at 260°C is approximately 35°C higher than eutectic soldering (225°C). The manufacturers of OSP have developed new OSPs to meet the market demands. These have a greater ability to withstand increasing number of thermal excursions and higher temperature, as needed for LF.

OSP products include benzotriazoles, imidazoles, benzimidazoles and phenyl benzimidazoles. Some of the newer OSPs have additives occasionally referred to as “oxygen scavengers.” These additives can stretch the performance window of the specific OSP. The more thermally robust coatings have significantly higher decomposition temperatures than the peak assembly reflow temperature. They require contact with appropriate flux and/or molten solder to penetrate the coating. They have longer shelf life, survive multiple reflow cycles and are more lead-free assembly compatible.

After more than one year of struggling with a specification for OSP, no consensus was reached, and no specification was set forth. This was due to the wide assortment of organic products that were used for solderability preservation for the various applications, each with its own thickness recommended values.

Acknowledgement

To date, all committee activities have been voluntary and acknowledgement is in order for the members and equally important for their respective companies that allow for the time invested by their employees. **PCB**



George Milad is the national accounts manager of technology at Uyemura International Corporation. He may be reached by [clicking here](#).

FlexTech Lauds Gov't Approval of Flex Hybrid Electronics

The industry consortium fostering the growth, profitability, and success of the flexible and printed electronics supply chain welcomes the U.S. Government's selection of flexible hybrid electronics (FHE) as the next topic for a Manufacturing Innovation Institute (MII). FHE was one of several topics under consideration and joins eight other technologies already identified for MIIs.

New Defense PCB Regulations Take Effect December 30

The changes to the U.S. Munitions List, which is regulated through the International Traffic in Arms Regulations, 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.

DoD Awards Accreditation of Trust to Hunter Technology

The company announces that it is one of only 60 suppliers to achieve an Accreditation of Trust from Defense Microelectronics Activity (DMEA), and is the only accredited EMS provider owned and operated exclusively in the U.S. As an accredited trusted supplier, Hunter addresses counterfeit risk using a proprietary system that meets all 12 requirements set forth by the Defense Federal Acquisition Regulation Supplement (DFARS).

Electric UAV Market to See 18% CAGR for 2013–2018

According to this electric unmanned aerial vehicles market (UAV) report, the industry will grow at 18.20% CAGR for 2013–2018. The cost-effectiveness of UAVs is a major draw for buyers in this market.

NASA Enters Collaborative Partnerships

The Collaborations for Commercial Space Capabilities (CCSC) initiative is designed to advance private sector development of integrated space capabilities through access to NASA's spaceflight resources and ensure emerging products or services are commercially avail-

able to government and non-government customers within the next five years.

Elvia PCB Renews Nadcap Certification

"The renewal of the Nadcap certification shows strong continuity in the technology and quality support that we provide to our strategic customers" commented Edouard Piedagnel, site Operations Director of Elvia PCB Group's main plant. "This is a true sign of maturity for Elvia PCB Group, which enables us to continue to offer the most up-to-date standards to our strong, growing aerospace customer base, both in Europe and the Americas," added Benoit Hareng, head of international sales.

Military Infrastructure, Logistics Market Post Growth

The report forecasts the industry to grow at a CAGR of 1.29% during 2014–2019. Developing countries in the BRIC are placing military infrastructure and technology revamp at the top of their priority lists.

ESA Performs Experiment with Force-Feedback in Space

NASA Astronaut Berry Wilmore conducted the Haptics-1 experiment on-board the International Space Station. The scientific technology demonstration experiment was conceived, designed, developed, and implemented by the European Space Agency Telero-botics and Haptics Laboratory and sets a new technology milestone for space robotics.

Air Traffic Control Equipment Market Report

ReportsnReports.com adds "Global Air Traffic Control Equipment Market 2015–2019" and "Global Air Traffic Management and Control Market 2014–2018" research reports to its online business intelligence library.

Report: Radiation Detection Devices for Military & Security

The market for radiation detection devices in domestic security will grow from a current market value of \$1.35 billion, to \$1.92 billion by 2022 and that the military market will grow from a \$617 million market today to \$868 million by 2022.

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The Future of Nickel in Nickel/Palladium/Gold Final Finishes

by **Rick Nichols**

ATOTECH DEUTSCHLAND GMBH

Final finishes can be subdivided into metallic and organic finishes. For the purpose of this article, the focus will be on the metallic finishes using the combinations of nickel (Ni) and/or palladium (Pd) and/or gold (Au). Variations on this theme are used extensively in the electronics market of today. The Ni/Pd/Au mutations are the inevitable result of technical requirement changes coupled with true and perceived acceptance within the industry. One such optimization is the phosphorus contents in the Ni and Pd layers. This subtlety will not be focused on in this article as the impact on the key topics is negligible.

This subgroup of metallic final finishes can also be further divided by their application bias. Traditional ENIG processes are biased towards using a protection layer to ensure extended lifetime reliability by protecting the base copper.

- Electroless Nickel/Immersion Gold (ENIG)—*the work horse*
- Electroless Nickel/Electroless Palladium (pure palladium and phosphor containing palladium)/Immersion Gold (ENEPIG)—*the all-purpose solution*

The next-generation surface finishes need to be biased towards satisfying lifetime requirements in combination with enhanced technical performance.

- Electroless Palladium/Autocatalytic Gold (EPAG)—*fine-line, high-frequency, solder and bonding application*

This broad segregation implies the inclusion or exclusion of Ni. This Ni protection layer (4–7 µm) has a physical impact on line and space capability whilst simultaneously having a negative impact on high-frequency applications.

The symbiotic relationship between technology influences and the resultant require-

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THE FUTURE OF NICKEL IN NICKEL/PALLADIUM/GOLD FINAL FINISHES *continues*

ments for the final finish is the driving force for this article. It is also the intention of this article to highlight the superiority of the direct palladium processes in achieving the expected requirements of the future.

Generic Technical Requirements

Regardless of the surface finish, there exist perceived and accepted minimum requirements for total functionality. The established standards will inevitably be augmented and many technology sectors will adopt their own performance criteria and expectations as the future era of high-frequency and fine-line applications become more necessary. It is also apparent that the new requirements will also include more economic wire bonding materials.

Despite being vital, solderability satisfies only part of the surface finish requirements. The surface finish must also provide adequate protection of the underlying copper circuitry from the time of substrate fabrication until packaging and assembly (copper corrosion on fine-line technology has the potential to impact significantly on signal integrity). The surface finish should not add to solder joint reliability concerns by contributing to the formation of undesirable intermetallic compounds (IMCs) or adversely affecting their growth. In other words, the bondability must be ensured.

Whilst negating all responsibility for looking into the future, some trends can be predicted as a result of integration trends. Circuit features continue to shrink and maintaining sig-

	Process	ENIG	ENEPIG	EPAG	
	Thickness	Ni: 5µm AU: 0.07µm	Ni: 5µm Pd: 0.1µm Au: 0.06µm	Pd: 0.1µm AU: 0.1µm	
Soldering	Multiple Soldering (> 3x soldering steps)	★	★	★	
	Solder Spread (Eutectic Solder)	★	★	★	
	Solder Spread (Lead Free Solder)	★	★	★	
	Solder Joint Reliability (Eutectic Solder)	★	▲	★	
	Solder Joint Reliability (Lead Free Solder)	▲	★	★	
Wire Bonding	Al Wire	★	★	★	
	Au Wire	▼	★	★	
	Pure Cu Wire	●	●	▲	
	Cu-Pd Wire	●	★	★	
	Ag Wire	▼	★	★	
High Frequency capability (Skin Effect)	Media and Sensor Technology	●	●	★	Future Considerations
Fine Line and Pitch Capability (>30:30µm)	Portable Media and Sensor Technology	●	●	★	
Shelf Life	Shelf Life Prior to Assembly	≥ 12 Months	≥ 12 Months	≥ 12 Months	
Very Good ★	Good ▲	Sufficient ●	Limited ▼	No ●	

Figure 1: The generic capabilities of Ni, Pd and Au final finishes. Note: Electroless palladium/immersion gold (EPIG) has not been included due to the process's copper corrosion and poor wire bonding attributes.



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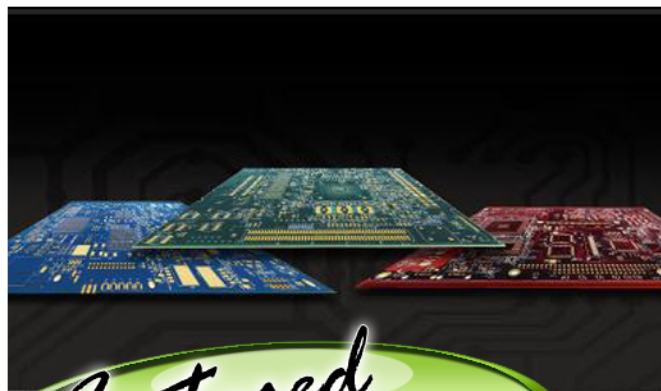
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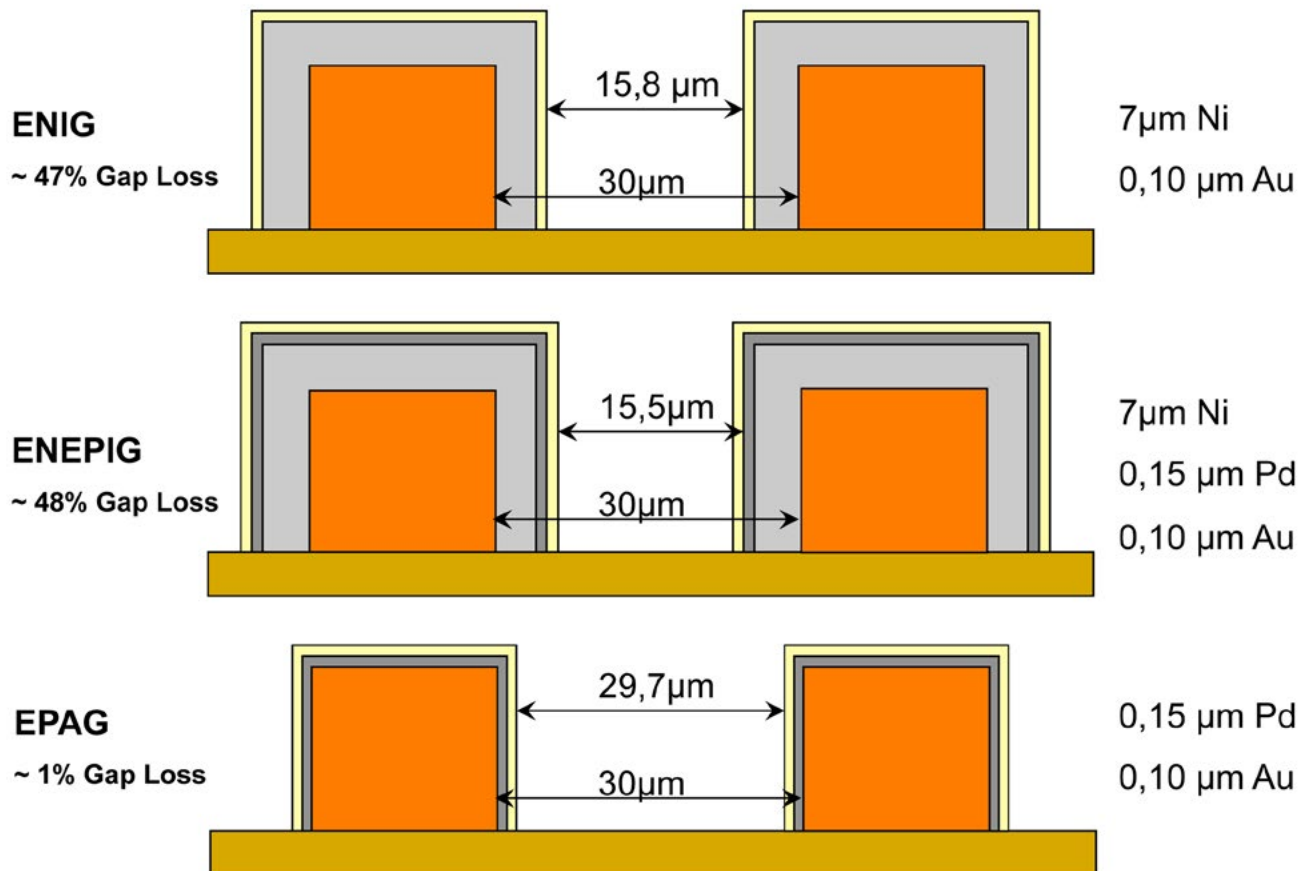


Figure 2: The impact of established Ni containing finishes on line and space.

nal integrity becomes even more challenging. This has a direct impact on assembly, and in response future surface finishes need to accommodate newer adaptations of thermo-compression bonding as the established solder technologies are also at the edge of their capabilities.

Topics and Considerations for Future Final Finishes

Fine-line Technology

The concept of fine-line technology already has to factor in the impact of etching to arrive at the required line and space. For example, to achieve 10 μm line and space the circuit will be designed at 12 μm line and 9 μm space. After such painstaking front-end design, final finishes are faced with the challenge of maintaining this integrity as far as possible. With future fine-line technology hinting at 5/5 and even 2/2 the

final finish can no longer afford μm scale protection layers such as Ni at 4–7 μm.

A further pitfall of the Ni inclusive technologies is their susceptibility to Ni spread and resultant shorting, even at an abnormally low Ni thickness (the low Ni is required to achieve the line and space criteria).

High-Frequency Capabilities

The widespread use of smartphones and tablets to support daily employment and leisure activities is tangible evidence of the future appetite for high data flow capabilities which necessitates by virtue high-frequency capabilities. Based on history, it is clear that this insatiable appetite will continue to expand.

At very high frequencies surface finishes with a nickel layer become critical. It is known that nickel plated on copper will cause an additional loss to signal propagation due to the so

THE FUTURE OF NICKEL IN NICKEL/PALLADIUM/GOLD FINAL FINISHES *continues*

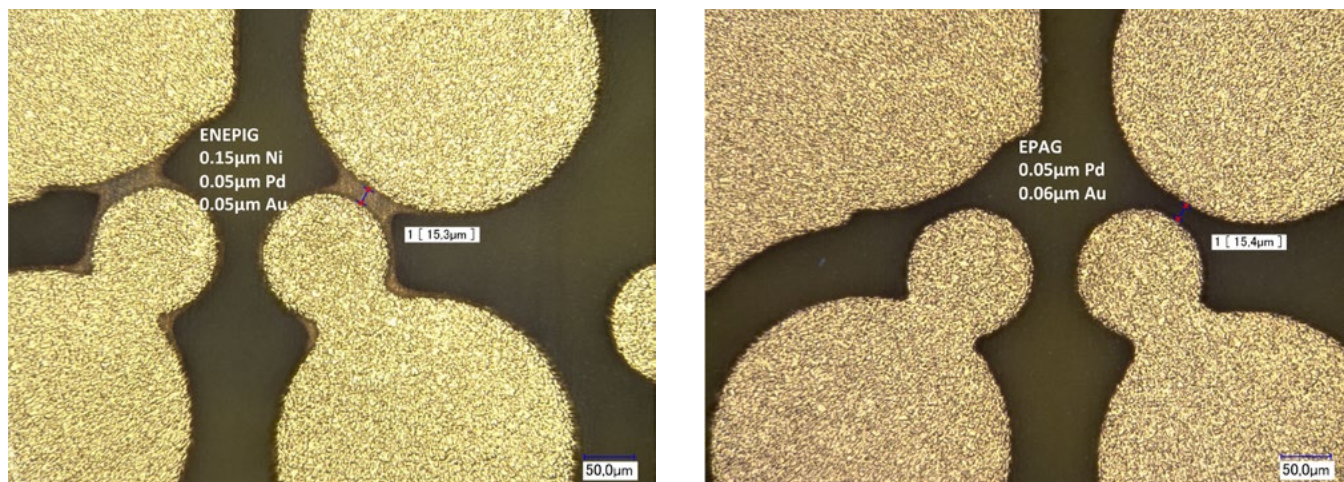


Figure 3: The potential for spreading when using a Ni inclusive finish.

called “skin effect.” Initially proposed by Horace Lamb in 1883 for spherical conductors, it was then applied to conductors of any shape by Oliver Heaviside in 1885 (Wikipedia). In laymen’s terms, the theory promulgates that induced electromagnetic fields (eddy currents) caused by alternating current will orientate the highest current density flow to the outside of the conductor. This is referred to as the skin effect. In turn, different conductor properties (electrical and magnetic) in conjunction with different frequencies will exhibit different skin depths (δ). With a given conductor property the skin-depth decreases exponentially with the increase of frequency.

The inclusion of Ni at 4–7 μm ensures that the primary signal will pass through the outer Ni skin. Not only is nickel a poorer conductor than copper, the effective area for the signal to pass through is greatly reduced. This is rather like placing your thumb over the end of a hose

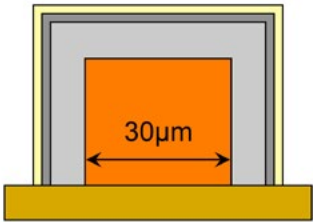
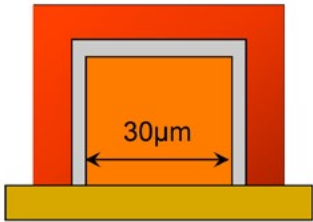
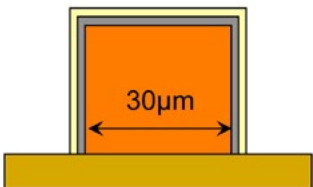
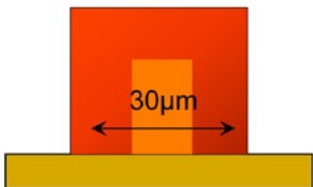
Process	100 kHz	10 MHz
ENEPIG		
$\delta \mu\text{m}$	~17	~1.7
High CD area μm^2 : Conductor μm^2	~81%	~11%
EPAG		
$\delta \mu\text{m}$	~210	~21
High CD area μm^2 : Conductor μm^2	100%	~91%

Figure 4: The impact of frequency on skin depth (δ) with reference to process application.

pipe, the resultant water flow is reduced and the directional flow is greatly disturbed.

The skin effect is one of the reasons why the electronics industry needs to entertain the notion of nickel-free surface finishes.

THE FUTURE OF NICKEL IN NICKEL/PALLADIUM/GOLD FINAL FINISHES *continues*

ENIG

Thousands of words have already been written about the work horse, ENIG, and many panels have been processed successfully using it. This is an established process that fulfils the requirements of many existing and past applications but falls short of the requirements promised in the future. As such this process will not feature further in this article unless to make a comparison.

ENEPIG with Thin Ni

Although in terms of words and production, the above is equally true for the 'the all-purpose solution' (ENEPIG) process, this is the most promising of the Ni inclusive processes. In addition to performing well generically there a frequent question is raised within the industry:

Why can't this process fulfil future requirements by employing a thin Ni layer?

Ni is employed as a barrier layer due to its dense crystal formations. The surface morphology, in turn is created by thicker Ni plating. This is the background for the IPC (4552 – ENIG and 4556 – ENEPIG), minimum thickness requirement of 3µm.

Higher Ni thicknesses positively influence the integrity of solder joints. By reducing the Ni layer to conform to dimensions dictated by EPAG, dramatic quality issues are encountered. Early indications of this can be found by examining the intermetallic compound (IMC) by SEM. Whilst the IMC created using EPAG has no detrimental impact to the solder joint, the IMC created using EN (low thickness) EPIG displays evidence of demarcation lines.

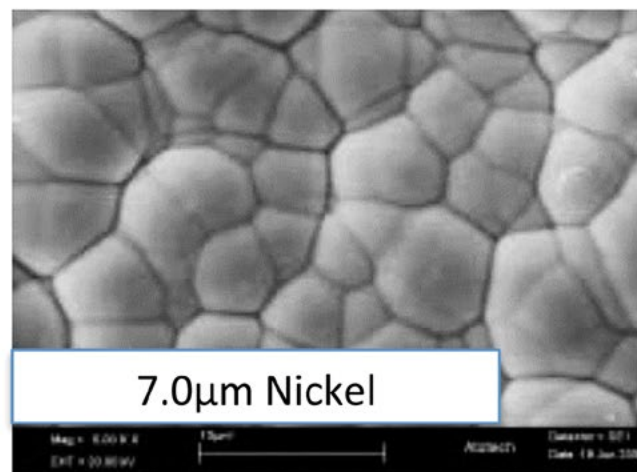
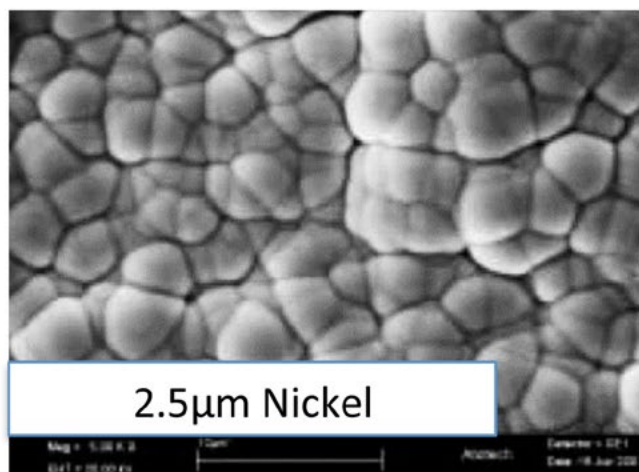
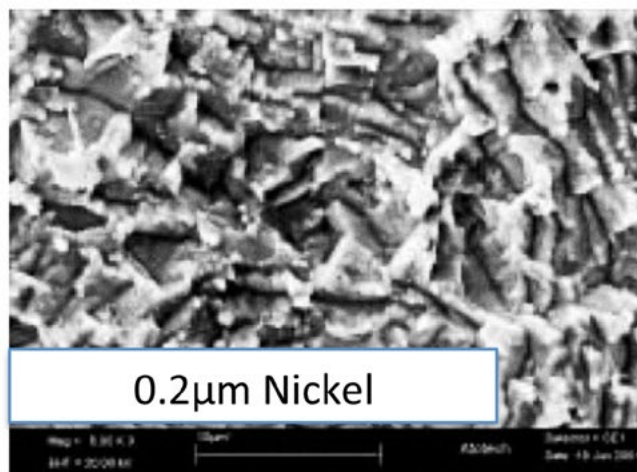
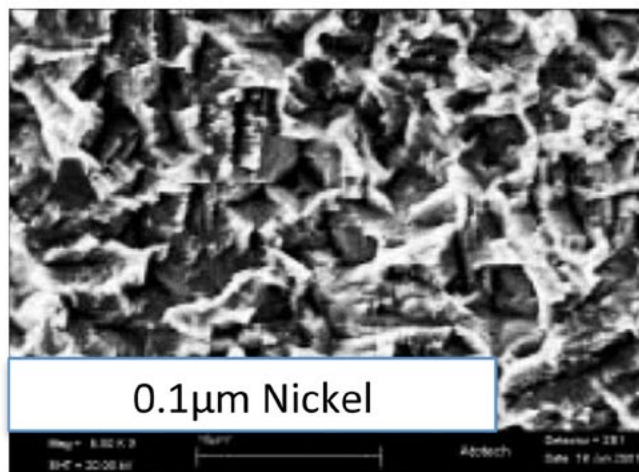


Figure 5: How the Ni morphology is influenced by the layer thickness.

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THE FUTURE OF NICKEL IN NICKEL/PALLADIUM/GOLD FINAL FINISHES *continues*

Demarcation lines are cosmetically alarming and create concerns for the end-user. This is not an acceptable situation. The impact of demarcation lines, in terms of quality, can be demonstrated using a drop test. The drop test is a simulation of a handheld device being dropped.

According to the drop test, the performance of the EPAG system is superior to that of the thin Ni ENEPIG process. In addition to the poor drop

test performance, the thin Ni layer becomes superfluous as a protection layer due to the low thickness and resultant poor morphology.

Silver Wire Bonding

Wire bonding is a field that is evolving like any other. Bonding speed, wire hardness and cost are all in the mix. Some 3D packaging philosophies mean that wire bonding is here to stay unless it is replaced completely by flip-chip derived bonding technology. Reduction in cost without yield and capacity loss is a major driver in this field. Pure copper wire bonding is one candidate for cost reduction, but this can result in other complications like component and equipment damage due to the forces and energy required. Gold, on the other hand, is the preferred and established medium, but recent exploration into silver wire bonding is proving potentially viable. The high potential for silver as a technical replacement for gold is the comparable softness of the metals. Figure 1 demonstrates that ENEPIG and EPAG are both able to deliver confidence in silver wire bondability. Additional to the technical similarities, silver also complies, in some way, to cost saving.

EPAG exhibits a wide working window with good performance indicators for silver wire bonding. Well known OEMs are also champion-

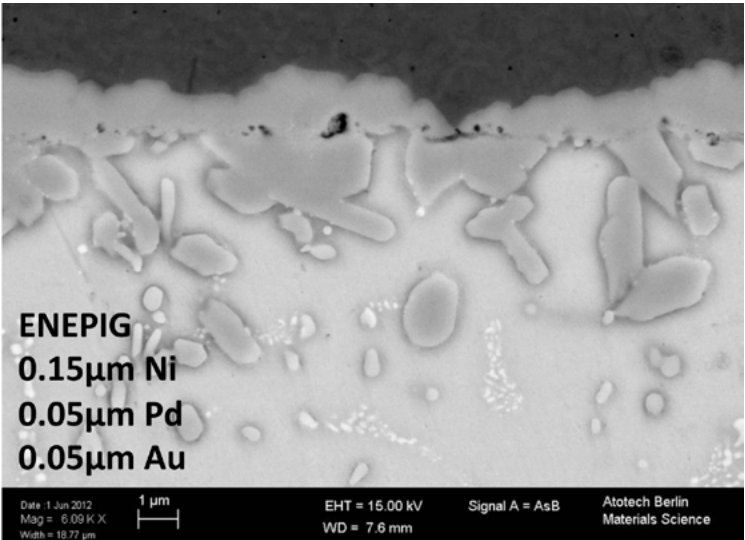


Figure 6: The impact of low Ni on demarcation lines.

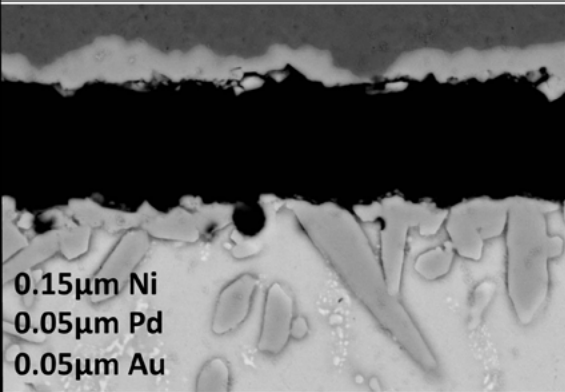
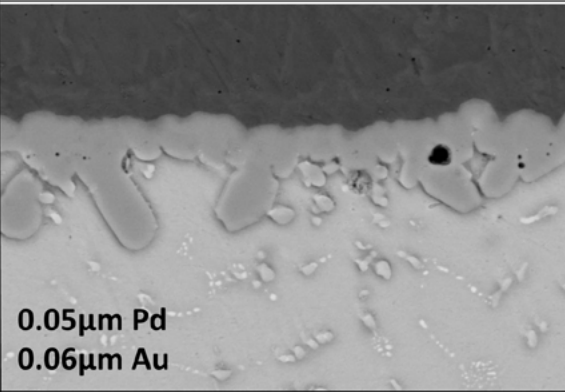
Process	ENEPIG	EPAG
SEM	 <p>0.15µm Ni 0.05µm Pd 0.05µm Au</p> <p>Date: 1 Jun 2012 Mag: 5.00 K X Width: 22.07 µm</p> <p>2 µm scale bar</p> <p>EHT: 15.00 kV WD: 7.9 mm</p> <p>Signal A: AsB</p> <p>Atotech Berlin Materials Science</p>	 <p>0.05µm Pd 0.06µm Au</p> <p>Date: 31 Mar 2012 Mag: 5.90 K X Width: 22.07 µm</p> <p>2 µm scale bar</p> <p>EHT: 15.00 kV WD: 6.8 mm</p> <p>Signal A: AsB</p> <p>Atotech Berlin Materials Science</p>
No of Drops	4	45

Figure 7: The performance comparison of the low Ni ENEPIG compared to the EPAG process.

THE FUTURE OF NICKEL IN NICKEL/PALLADIUM/GOLD FINAL FINISHES *continues*

ing this direction for wire bonding. The results for Cu wire bonding are also acceptable.

A Look into the Future

The roadmaps, available in the public domain, according to the following OEMs, IPC, iNEMI, ITRS and Jisso, predict fine-line technology. This, by definition, has a knock on impact to pitch miniaturization. This applies equally to organic and inorganic substrates.

As part of flip-chip bonding technology, the tried and tested reflow bonding is limited with regard to in/out (I/Os) density. With the value of real estate becoming so important, the space utilized by reflow bonding techniques is becoming an obstacle. When discussing real estate, it is common to solve the issue with an expansion in the Z-axis. In the property market this is fine, but in the portable electronics market this direction is also becoming crucial. The Z-axis constraints are high-speed signal transfer and signal integrity. The reflow process requires the application of solder. Aside from this procedure being already at the application limit, the utilization of solder does not lie within the remit of

controlled Z-axis expansion and is also a comparatively poor conductor compared to copper or other more noble metals. Here we have established that not only will the I/Os increase in density (decrease in pitch), but the pillar height (standoff height) will also become paramount to future developments. To this end Atotech is cooperating with Georgia Institute of Technology to assess the viability of using EPAG as the pillar and pad finish for thermo-compression bonding.

There exists a prior art to thermo-compression bonding (TCB). These can be characterized in Figure 9.

Although the prior art technologies are proven, there are some viable benefits in using EPAG as the copper interconnect. Not only can the key performance indicators or benefits can be compared to direct Cu-Cu bonding, but can be improved upon.

Conclusion

Although ENIG and ENEPIG still have a place in a supplier's portfolio, the future is looking bright for the EPAG process. Hinged on the

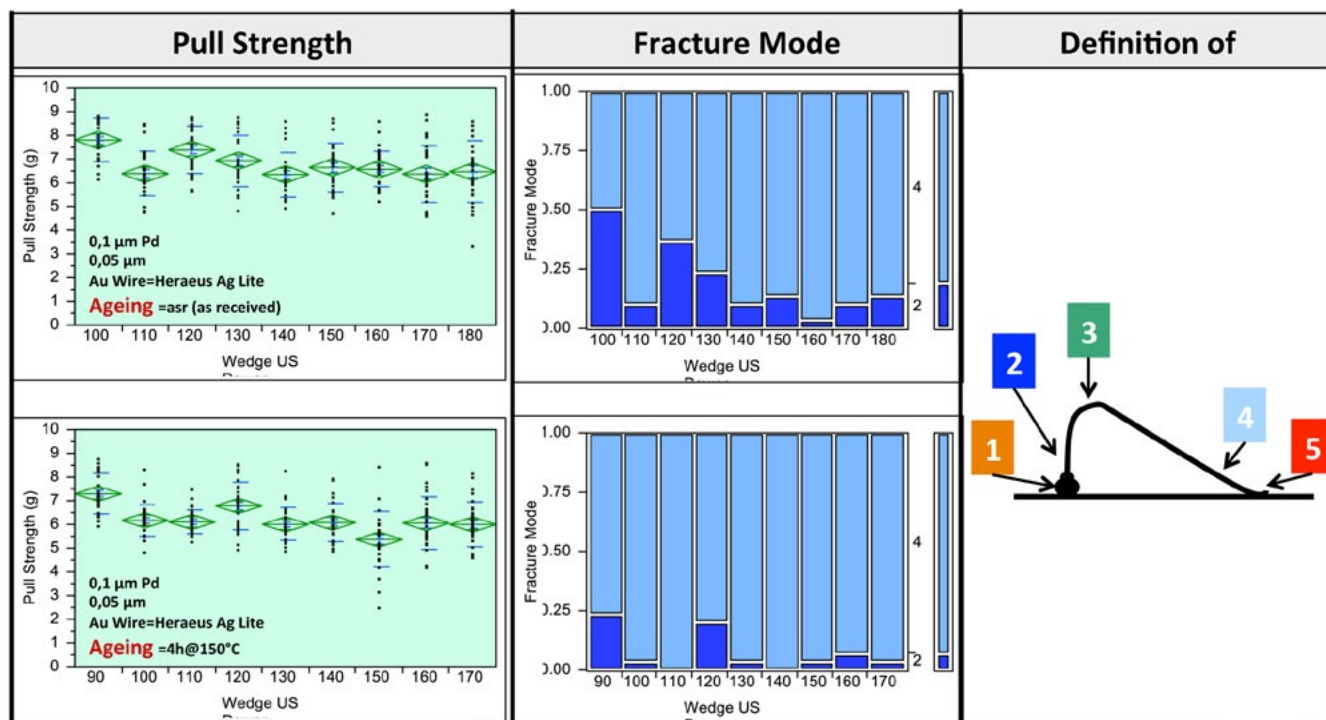


Figure 8: Performance of EPAG for AG wire bonding.

THE FUTURE OF NICKEL IN NICKEL/PALLADIUM/GOLD FINAL FINISHES *continues*

		Prior Art		EPAG as Low T°C Cu interconnect
		Current Direct Cu-Cu Bonding R&D	Curent Cu pillar with Solder-Cap Process	
Pitch		Pure Cu interconnection <10µm	Cu: Solder interconnect ~ 25µm	Cu interconnect <10µm
Properties	Electromigration	> 1000 hours @10 ⁻⁶ A/cm², 130°C	10 ⁻⁴ - 10 ⁻⁵ A/cm²	> 1000 hours @10 ⁻⁶ A/cm², 130°C
Manufacturing Considerations	Bonding T°C	> 250°C	~ 260°C	< 200°C
	Bonding t (s)	600	<60	30
	Bonding Pressure	High	Low	High
	Bonding Environment	Noble atmosphere or vacuum	Air	Air
	Non-Coplanarity Offset	<< 1µm (no bump collapse in solid-state bonding)	>3µm (high risk of bridging)	>3µm (bumping collapse under pressure, minor lateral deflection)

Figure 9: The characteristics of prior art TCB compared to EPAG. (The highlights are in green.)

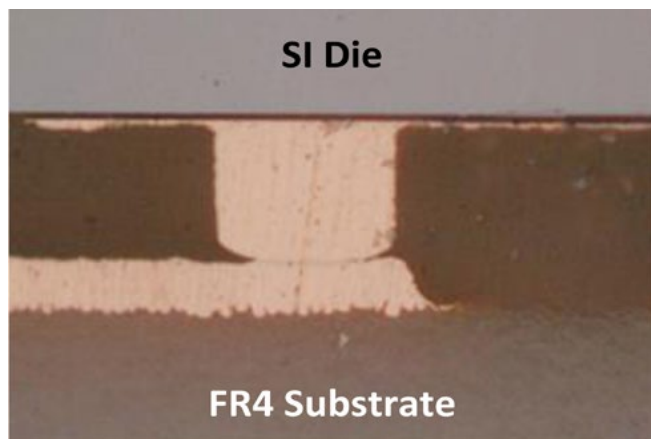


Figure 10: This demonstrates initial results achieved at the Georgia Institute of Technology (TCB at 190C – 3s – 365MPa with perfect electrical yield [1-2Ω]).

discussions above it is apparent that Ni presents some difficulties when considering its suitability within the scope of future requirements. The target of this article is to highlight the superiority of the EPAG process in ascertaining the goals of the future. If this article has not been convincing enough there will be more discussion on this topic at the [iMAPS 2015](#) in Orlando, Florida in March. **PCB**



Rick Nichols is global product manager, selective finishing, at Atotech Deutschland GmbH. He may be reached by [clicking here](#).

Flex Plastic Computer Screens Nearing Reality

Researchers at Japan's National Institute for Materials Science revealed that improvements should soon be expected in the manufacture of transistors that can be used to make flexible, paper-thin computer screens.

The scientists reviewed the latest developments in research on photoactive organic field-effect transistors, devices that incorporate organic semi-conductors, amplify weak electronic signals,

and either emit or receive light.

Organic field-effect transistors (OFETs) were developed to produce low-cost, large-area electronics, such as printable and/or flexible electronic devices. Progress has been made in the development of light-emitting organic field-effect transistors (LE-OFETs) since they first appeared in 2003.

Research in this area has resulted in advances in the manufacture of novel organic photonics applications using cost-effective approaches. Light emission efficiency and brightness of these transistors will soon improve. And the production of new display technologies is expected to be the result of further research.

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PCB007 Supplier/New Product News Highlights



Rogers Inks Definitive Agreement to Acquire Arlon

"This transaction is truly a unique strategic fit for both Rogers and Arlon. We are energized by the opportunity to serve our customers with our complementary capabilities and technologies in circuit materials and engineered silicones and to enhance value for our shareholders," says Bruce Hoechner, president and CEO.

Elekonta Marek Installs Orbotech's Nuvogo 800 DI System

Orbotech announces that earlier this year German PCB prototype specialist Elekonta Marek deployed an its Nuvogo 800 Direct Imaging (DI) system.

Calumet Boosts Quality with New Investments

Over the past two years, Calumet Electronics has invested close to \$3 million in capital equipment, infrastructure improvements, and technology upgrades, reinforcing its commitment to quality and turnaround time for customers.

Excellon Installs 136L Intelli-Drill at Bay Area Circuits

The Excellon 136L Intelli-Drill System with a large work area of 30 by 36 inches and fast, accurate axis positioning via linear motor technology, makes quick work of large panel prototype as well as production PCBs.

atg Luther & Maelzer Releases A8a Test System

The A8a provides significant cost advantages compared to fixture testers for small and medium batches and fully meets the requirements in its main application field: the electrical test of HDI products for smart phones, tablet, and PC motherboards.

Isola Taiwan Secures ISO 50001 Certification

Isola Group S.à r.l. announced today that its subsidiary, Isola Asia Pacific (Taiwan) Inc. has received ISO 50001:2011 certification by SGS, the world's leading inspection, verification, testing and certification company.

Park Electrochemical Reports Sales Drop in Q3

Park Electrochemical Corp. reported net sales of \$34,679,000 for the third quarter ended November 30, 2014 compared to net sales of \$39,678,000 for the third quarter ended December 1, 2013.

Xcerra Intros New Tester from atg Luther & Maelzer

Xcerra Corporation announces a new product from its atg Luther & Maelzer brand, the A8a. The A8a test system provides the flexibility of flying probe testers while delivering high-throughput testing for bare board PCBs.

Nordson MARCH Demos FlexTRAK-CD at NEPCON

Nordson MARCH announces that it will be demonstrating its FlexTRAK-CD Plasma System for high throughput processing of lead frame strips and other strip-type electronic components, up to five strips per plasma cycle, at NEPCON Japan.



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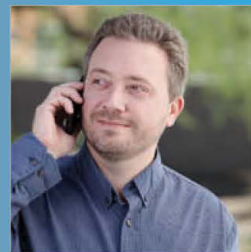
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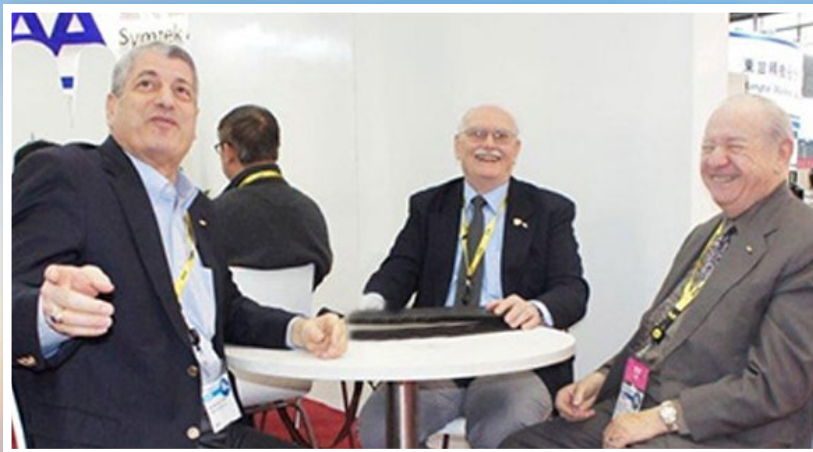


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China Outlook

An Interview with Hamed El-Abd, Lionel Fullwood, and Gene Weiner of WKK

by **Barry Matties**
I-CONNECT007

During the recent HKPCA show, I had the opportunity to catch up with Hamed El-Abd, Lionel Fullwood, and Gene Weiner of WKK. Our discussion covered an array of topics, from politics to new PCB factories and what it takes to stay competitive. These three men have spent years in China, so it's always informative to speak with them about China's PCB manufacturing industry and the global electronics market. A transcript of the interview follows.

Barry Matties: *Here with me today is Hamed El-Abd, Lionel Fullwood and Gene Weiner from WKK. Welcome, guys.*

Gene Weiner: Barry, it's good to see you again in China, the No. 1 economy in the world as of this quarter.

Barry: *Thank you, and that's what I've read just this morning.*

Gene: And that is strictly because of numbers, not because of technology. The leading technology here is still coming in from the foreigners,

including the Taiwanese, who are classed as foreigners.

Barry: *Gene, you've been coming to China for many years now, correct?*

Gene: Since 1983.

Barry: *One thing that strikes me is the amount of change that has happened in just the last five years in particular. What changes have you seen, and what's your opinion on it?*

Gene: Well, with the change, a lot of it is superficial. Much of it is a new, younger government tightening up, and much of it is from a stronger economic position globally and a stronger military. The Chinese have put themselves in a position to be a power player, if not the power player, in the world. They're still copying, copying, copying, and not paying much attention to specs. Mostly it's homegrown products for homegrown companies, with the best technology still coming from Europe, the U.S., Japan, and Taiwan. From Taiwan I would say it's the application of the technol-



February 2

IPC/EIPC Conflict Minerals Workshop
Paris, France

February 4

IPC/EIPC Conflict Minerals Workshop
Munich, Germany

February 4–5

IPC Standards Meet High Reliability Requirements for PCBs and PCBAs

ETECH Kerkrade, Netherlands

February 6

IPC/EIPC Conflict Minerals Workshop
Woking, Surrey, United Kingdom

February 20–26

IPC APEX EXPO Conference and Exhibition

- IPC Designer Certification Sessions
- IPC Design Forum
- EMS Program Management Training
- Professional Development Courses

San Diego, CA, USA

April 29–30

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- Best Practices in Fabrication
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June 9

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Discussion with international experts
N. New Jersey, USA

June 9–11

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- Advanced Troubleshooting

Chicago, IL, USA

June 10

ITI & IPC Conference on Environmental and Government Regulation

Discussion with international experts
Chicago area, IL, USA

June 12

ITI & IPC Conference on Environmental and Government Regulation

Discussion with international experts
San Jose, CA, USA

September 27–October 1

IPC Fall Standards Development Committee Meetings

Co-located with SMTA International
Rosemont, IL, USA

September 28

IPC EMS Management Meeting

Rosemont, IL, USA

October 13

IPC Conference on Government Regulation

Discussion with international experts on regulatory issues
Germany

October 13–15

IPC Europe Forum: Innovation for Reliability

Practical applications for meeting reliability challenges like tin whiskers, with special focus on military-aerospace and automotive sectors
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October 26–27

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October 28–29

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Presentations will address Flex and HDI challenges in methodology, materials, and technology.
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November 4

PCB Carolina 2015

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December 2–3

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- Advanced Troubleshooting

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December 2–4

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

Shenzhen, China

CHINA OUTLOOK *continues*

ogy improvements done by ITRI, their government sponsored research, as well as their major companies.

Barry: *In comparison to the U.S., what do you see happening from your point of view?*

Gene: The U.S. is struggling to maintain a position with a government that appears confused by its economic, domestic, and foreign policies. However, quietly happening in the U.S., and not for volume but for technology, we're seeing some great advances in R&D: in chips, packages, and chipsets, as well as the quiet building of new automated factories in captive shops not publicly known. Lockheed has three in-house printed circuit shops, and the public thinks there's only one. It's now become an open secret that Intel is building a shop in Chandler, Arizona. Two weeks ago, Lionel and I visited Whelen Engineering's new factory in New Hampshire, and it's the first fully automated new printed circuit shop in North America—and I really mean fully automated. The only things that were not part of the automation line were a separate semi-automatic layup set-up and multilayer pressing line by Burkle, an offline ENIG electroless nickel/gold, and a plasma machine. Everything else was inline, automated, with a very modern design.

Instead of treating the air and water of the entire building, they use semiconductor techniques with tunnels around the equipment, making it easier to maintain the environment, and they didn't have to get one single permit for waste treatment because the plant is almost 100% recycled air, fumes, and liquid. Copper is plated out of the spent etchant, the ammonia is recaptured and put back in—it was amazing. And we were watching the first runs of 100 panel lots; Lionel is doing some evaluation of some new imaging equipment that we can't give you the details on until perhaps spring.

Barry: *Are they in production now?*

Gene: They're debugging the systems. They started from zero, they put in a building, and they have 12 engineers and technicians running two shifts a day.

Barry: *They purchased a lot of U.S. fabs as well, didn't they?*

Gene: Yes, that was interesting. They have a custom-designed plasma, they have a custom-designed waste treatment system designed by the general manager of the plant—an oldie in our industry, Alex Stepinski of Sanmina and other companies in the past. They have some innovative approaches from the handling of the legend ink to the handling of solder mask and protecting the layer that goes down before the legend ink. It was highly innovative; their plating was all horizontal Atotech equipment, and the machines were dual routers, single-station, high-versatility. And they paid 10% more than, say, a 5–6 spindle set-up or the equivalent. I said, "Why did you do that?" They said it was because the versatility and productivity is greater. I think much like many other things, the days of conventional electroless copper are gone. The days of conventional drill sets are gone, although there are always going to be some. The days of imaging using phototools are waning. It will be a minor part of production within 10 years, except for maybe the Chinese copycats.

Barry: *I visited DSG in Dongguan recently, and I was thinking here's a company that came in not with a Chinese mentality, but with a business mentality.*

Gene: A European business mentality—very smart and very successful.

Barry: *They set up a factory with 470 people and they're pumping out \$60 million in sales and plan to double that without adding additional staff. I'm wondering why can't we do this?*

Hamed El-Abd: Nobody wants to spend the money.

Gene: Well, we can do that. Yesterday, Phil Plonski, senior managing partner of Prismark, presented a paper. One of his conclusions is a little beyond that which his partner gave at the IPC meeting in North Carolina, in that we have two opposing forces at work here: the need for

volume at a lower cost and the need to develop and insert new technology and support the funding. The OEMs are out of it, many of the ODMs have decided to brand their own product, and now we're seeing the Chinese smartphones in Europe and the U.S. In addition to that, the supply chains have concentrated. WKK is a major supply chain supplier. As the industry consolidated, they consolidated their supply chains. So for a small independent that has a breakthrough, to break into the trusted supplier for the large guys running millions of parts is very difficult. We have opposing forces and a new method of marketing the entire thing.

Lionel Fullwood: I think you have also got the situation where the local and central governments supporting China are all for the companies. They understand that this is a competitive world; they understand that their market is essentially outside of China, at least for the foreseeable future, ergo the whole mechanism is such that you could get a shipment out of China in one day. It appears, and this is my personal opinion, that the U.S. government is adversarial rather than supportive of business developments in the U.S. Even clean business, even automated business, because as you said it doesn't matter where that factory is, you can put it anywhere in the world that's supportive, but China is much more supportive of the concept than we presently have in North America.



Barry: *Interestingly, while I was visiting DSG, Project Manager Mauro Dallora said that the government is encouraging not bringing in employees and instead bringing in automation, because the government realizes they have to go this route to stay competitive. At least that's how I interpret it.*

Gene: Additionally, they have to do it to gain the world standard in quality. If they don't do this, they can't compete in quality, globally. There's an interesting thing yesterday when I went to Hall 2, which focuses just on chemicals and materials. I spoke to the managers of one

company, and they said their revenue doubled this past year, but their profits declined. I asked why, and he said to look at all of the copycat, reverse-engineering companies in chemicals and materials here in China. They are all new, and they're claiming to have everything. They first thing they say is, "My boss used to work for MacDermid," or "My boss used to work for Dow Chemical." The second thing they say is, "I have the cheapest parts." Nowhere do they talk about service, nowhere do they talk about performance, and nowhere do they talk about consistency. So, in a way, many Chinese are succumbing to the conclusion that price is king. Not cost—price.

Barry: *That's interesting.*

Gene: It's a different look.

Barry: *What do you think about China, Hamed? We talked about China a few years back. In the last five years, has your perception or attitude about China shifted at all?*

Hamed: No, it hasn't shifted that much really. I think that the Chinese are going to be faced with a lot of very difficult problems. As Gene was just saying, everybody is copying each other and it's creating a situation where you really don't have good quality products, because one guy copies another guy who copies another guy. There's no respect for the information, technology and the proprietary technology that you have out there. But given the country as a whole, they're having a lot of problems. First of all, their healthcare system is basically not really in place, and the government is very seriously concerned about how they're going to deal with that. Gene was mentioning a minute ago about the shift in power and how they're now No. 1 and the U.S. is No. 2. They do believe that they are the real economic power today. They do believe that they're building a military which will be able to show the force that they have, as the United States has done for years.

I have serious doubts whether they are really there yet or not, because they're copying in that area as well. You know, they just released a fighter jet which copies the F-35, but it will be five or six years before it can really run under

CHINA OUTLOOK *continues*

combat conditions. There are a lot of things that you have to be concerned about, and one of things that I have mentioned over and over is the amount of automation that is coming here. As a matter of fact, in order for these big boys to compete, they have to accelerate automation. We just had a customer this morning tell us, "I want that machine, but I want it automated. If it's not automated, I'm not going to get it. I want full automation."

So then you have to ask yourself a question, if they automate as much as they're going to be automated, what are you going to do with all the people? America has 300 million people and they have 1.5 billion. There's going to be some uncertainty, because their population is so large and they're still not at the education level where they can do other things and it will definitely affect their economy. We were talking the other day about Foxconn putting in 100,000 robots this year, and next year they want to up it to 1 million robots, and the year after that even more. But what are you going to do with all the people? We have to begin to think about that today.

Barry: *Interesting that you mention it, because I was looking at the new generation of young people here and it's so different from just 10 years ago—their attitudes, the status that they're going for with iPhones and such, and especially the amount of cars. Holy simoly, there used to be just one or two cars in a parking lot!*

Hamed: And they're all good cars!

Barry: *Yeah, they're Audis and BMWs and so on.*

Lionel: The problem with the young people here is that they've all been weaned to have an expectation of material growth, and there's just not going to be that much available. It's going to cause a lot of unrest because of this expectation level. "Hey, why can't we have that? Why can't we have it now?"

Gene: Yes, there are several things. First will be the expectation. Secondly, more and more

Asian business managers are saying, "We no longer trust the Americans; it's too expensive to do business there. Yes, we like to own property there, but I don't know if we want to actually be there." At the same time we look at the other changes on taxes—we're still increasing taxes and they are not. So even if we built these things in the states, to whom are we going to sell them? We're importing it but we still have to export it.

Hamed: I think that Gene makes a very good point. If the United States government continues to increase taxes on American business, why should we do anything there? You're a businessman and you're going to go where the best deals are. Our corporate tax rate today is 39%, and it's crazy! We used to joke about the Germans having higher taxes than us, and now we're higher than the Germans. It's ridiculous. I'm just hoping that the next administration begins to address these issues, because this administration doesn't get it at all; business will continue to decline and leave the country. The other very important point that Gene and Lionel mentioned earlier is that at the new Whelen factory, a fresh new PCB plant and one of the first built in 20 years in the U.S., only 12 people were running the entire factory. This is where we need to be going to bring back business to America, but at the same time, what are you going to do with the people who aren't going to have jobs? Do you think Ferguson was the beginning?



Barry: *That was just a demonstration of what a fine line civility and chaos live on.*

Gene: Well, that came up in another conversation with some of our Asian friends yesterday, too. They said in Hong Kong, the civil disobedience leaders voluntarily walked into police stations even though there was no arrest warrant out and said here we are, and then they were sent home and they walked out. In the U.S., following the due process of law with a result according to the due process of law, we have riots and parades all over the country. And I cannot

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CHINA OUTLOOK *continues*

believe they were not organized. They were all happening simultaneously, at the same type of targets, carrying pre-made banners; if you look closely at the news videos you will see people in the crowds with microphones and so forth coordinating the whole thing. The Chinese must look at us and say, “And you were talking about our little demonstration?” We’re worlds apart and they think we’re headed towards becoming a Third World country, and that they’re fast moving to a first world position.

Barry: *Well, bringing it back to the PCB industry, it’s all about automation, automation, automation.*

Hamed: Absolutely, if you don’t have automation and you are going into automation, it will have an effect on your ability to sell. These people need to make money, and the other issue is that in China the increase in salaries of factory workers is mandated by the government. So if you look at the last few years, the salaries have increased 20% a year, and more than a 100% increase in the last five years. If business continues to go to China, that’ll force companies to automate, and they’ll have to start getting rid of these workers. The government is also mandating things with regard to social costs, health care and things like that, which people here didn’t have before. Now all of these factors are coming in to add cost. It is now cheaper for you to get a senior level engineer in Malaysia, Thailand, and Vietnam than it is one here in China. So, how soon before people say, “Hey, maybe we need to move...”?

Lionel: It does also require innovation. We can’t keep using the same old technology. We have to have, for example, better and more efficient ways of transferring data to the substrates. You have to be able to provide the quality that’s needed at the substrate level, because as you drive the geometries down, the incidence of fails and defects goes up. Unless you innovate in that area, you’re not going to get the yields you need to provide the products at the prices we need.

Gene: This leads to the newest generation of opportunity for actual equipment. As we are all now working with the cloud, we now have

the fog coming, which is local and regional versions of the cloud where you can extract information locally where you need it, instantly, and then put it back. And that’s going to create another whole industry of electronic arts as well as software.

Hamed: There is one other area which people don’t even talk about, and it’s even complicated for me to talk about it here, but it’s the massive amounts of corruption, even within our industry. People want to sweep this under the rug, and you can sweep it under the rug all day long, but only the other day we were sitting here talking to one of the very top companies in all of China. They were saying how they know what’s going on even within their own company and they just look the other way. Of course, we know that the Chinese government is addressing it, but the government is addressing it at the government level and they haven’t even started to do this at the business level, and it is a very serious problem. They have just put under house arrest or in jail 50,000 government employees—that’s a huge number and that’s just scratching the surface. You can imagine how high that number would be in business. As a public company, it’s not in our DNA to even think about things like that, but when you deal with it on a daily basis we are forced to walk away from order after order. The way people are getting that business is because of that. This is different than the West. China is going to have to learn a very hard lesson sooner or later.

Gene: Wouldn’t it be nice if in America, we followed the rule of law that we talk about and put under house arrest 50,000 government employees that are corrupt? (Laughs)

Barry: *The thing that is interesting, though, is the rate at which technology is changing and how we’re going to start applying circuits. In my mind, 3D is something that is really going to change everything.*

Gene: Well, that takes away a lot of the circuit boards though. About 3–4% of the surface of a circuit board has already converted to packaging for the past year of what would have been circuit

boards. We will continue to see that, but when we talk about 3D though—rather than stacked vias, which are coming but it's too costly yet, especially silicon through vias—the costs are still prohibitive for now and a percentage of that will be integrated into chipset. But the total volume of parts will go up and there will be more of the smaller parts. It's a fact that last year the surface area of substantive laminate consumed went down. This will be a trend. The net effect is that my guess is, in the next five years globally, we'll see an increase in PCB production of 4–7%, with the leaders being packaging and automotive.

We see a great deal of movement towards sensors that detect motion nearby and the direction of the nearby motion. These are going into automotive things, smart tablets, cell phones, etc. So that business is going to continue to explode. If I could put my money on it right now, the way things are in the world, I'd say military boards are going up, though they'll be more secretly done and they'll be in the whole country. Medical boards will continue to increase, though

it's not a big number, but it'll be in the domestic products in Europe and the U.S. In China, even though the doctors are hustlers here, they don't want to touch anything unless it's FDA approved, and that's the United States. Although some of the medical PCBs are made here in China, they're not from as sophisticated a plant as the U.S. boards.

Barry: Well, gentlemen, it's been great chatting with you. I always enjoy our conversations. Thank you. PCB

Hamed El-Abd is the president of WKK Distribution Limited.

Gene Weiner serves on the board of directors of WKK Intl (Holdings) Ltd., and is the founder of Weiner International Consultancy.

Lionel Fullwood is the technical director of WKK Distribution Ltd.

VIDEO INTERVIEW

Dongguan Somacis Graphic PCB Co. Ltd. (DSG) Invests in the Future

Recently, I-Connect007 Publisher Barry Matties toured Dongguan Somacis Graphic PCB Co. Ltd. (DSG) in Dongguan, China. In the last year alone, DSG invested more than US\$10M in new equipment. COO Mauro Dallora said that the company now has plans to double its revenue without hiring additional people, which would mean generating more than \$100M with a team of approximately 500 people, or more than \$200,000 per employee. That's a strong ratio! Watch the interview here.



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Here are just a few highlights of what you can expect this year:

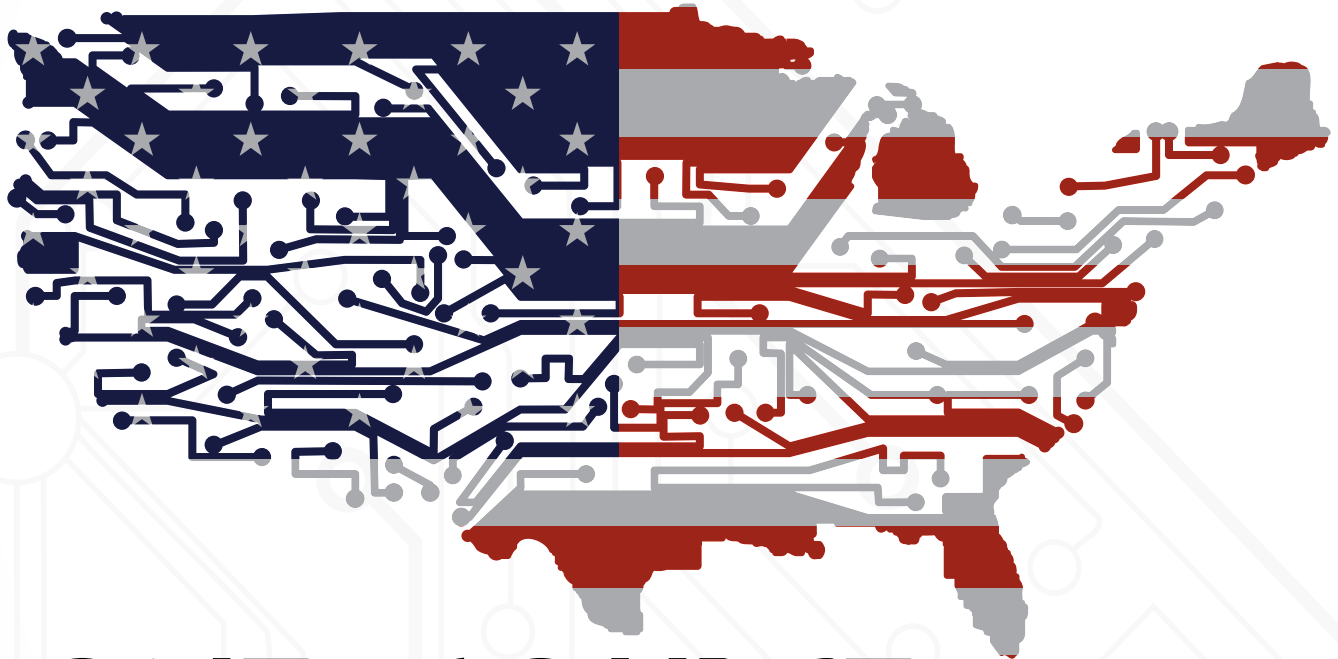
- This year, IPC APEX EXPO returns to sunny San Diego, California, at the San Diego Convention Center. More than 440 exhibitors will come together this year (even more than last year!) to showcase new technology and participate in technical conference sessions, professional development courses, certification opportunities, and more. Click here for the [event schedule](#), or visit the [IPC APEX EXPO 15](#) homepage for complete information.
- Here are just a few highlights of what you can expect this year:
- 440 exhibitors showing equipment, materials and services for printed boards and electronics manufacturing.
 - The largest technical conference in the industry, worldwide. Presenters will be offering new research and innovations from experts in the fields of electronics assembly, test and board inspection, and board fabrication and design.
 - Free industry poster sessions.
 - Professional development courses that provide comprehensive updates on trending industry concerns.
 - Standards development meetings that will help shape the future of our industry.
- IPC International Hand Soldering Grand Championship on the show floor.
 - Show floor welcome reception on Tuesday that displays cutting-edge products and services in the New Product Corridor and the IPC Bookstore.
 - Networking opportunities including the International Reception, First-Timer's Welcome, IPC Tech Talk, Women in Electronics Networking Meeting, and IPC Government Relations Committee Open Forum, designed to allow attendees to meet colleagues, get updates on key issues and share ideas.
- To register to attend IPC APEX EXPO 2015, [click here](#).
- Traveling to San Diego and need help? Visit the IPC APEX EXPO [travel page](#) for hotel, directions, and airfares (including a United Airlines 5% airfare discount offer).
- Be sure to keep an eye on the [I-Connect007](#) site throughout the show for breaking news and event coverage from the show floor. If you're at the show, stop by our booth—#2645—and say hello to the I-Connect007 team, find out how you can become a contributor, or share your thoughts on our content and coverage.

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Opening Keynote Address:
Tuesday, February 24, 2015
8:30–9:30 a.m.

The Xbox Story: Lessons in Strategy, Team Management and Entrepreneurship

Robbie Bach
Former President of Entertainment & Devices at Microsoft, Xbox visionary and civic activist



Chances are you or your kids own an Xbox, or at least have played games on one. But do you know the story behind this groundbreaking game console? The Xbox saga—from garage-shop inception, through numerous crises and challenges, to ultimate business success—is a multi-faceted tale with several compelling story lines. Bach joined Microsoft in 1988 and worked in various marketing and management roles for 22 years. Beginning in 1999, he led the development of the Xbox business, including the launch of the original Xbox and the highly successful follow-up product, Xbox 360. Bach will speak from his experience as the chief Xbox officer, taking the audience “behind the scenes” and sharing the triumph of a strategic process that brought together a disparate group of talented individuals. Bach will explain how this collection of individuals transformed into a powerful team that applied entrepreneurship principles to build a successful consumer business within the larger Microsoft structure.



XBOX 360

Day Two Keynote Address:
Wednesday, February 25, 2015
9–10 a.m.

Flying Saucers and Science/ Science was Wrong



Stanton Friedman
Nuclear Physicist, UFO Researcher

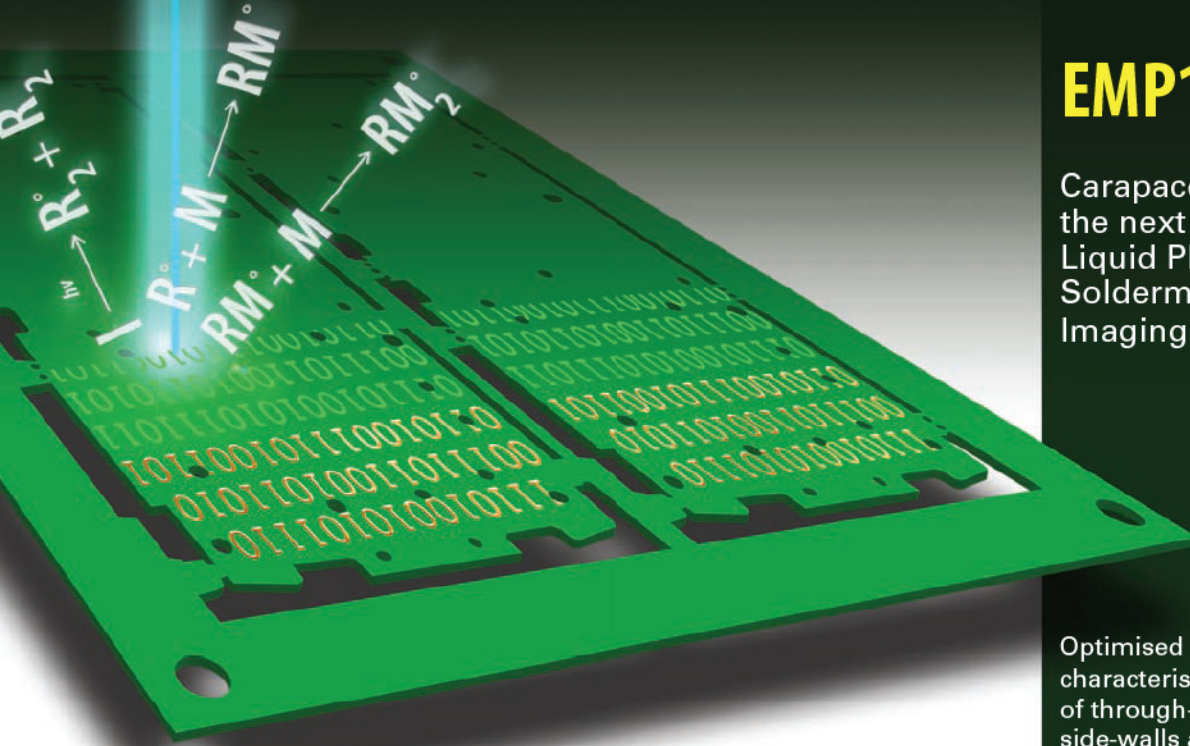


Do you take UFOs seriously? Nuclear physicist and lecturer Stanton T. Friedman does. Friedman will challenge the audience as he draws on more than 40 years of research on UFOs, and his work on a wide variety of classified advanced nuclear and space systems. He will answer a number of physics questions in layman's terms, and establish that travel to nearby stars is within reach without violating the laws of physics. The audience will journey with Friedman to locations in the universe where aliens reside, learn why they've come to Earth and their motives to cover-up their visits. You'll never feel the same about the universe again.

Friedman was a nuclear physicist for 14 years for companies such as GE, GM, Westinghouse, TRW Systems, Aerojet, General Nucleonics and McDonnell Douglas, working in such highly advanced, classified, and eventually canceled programs as nuclear aircraft, fission and fusion rockets and various compact nuclear power plants for space and terrestrial applications.

Since 1967, Friedman has presented at more than 600 colleges and 100 organizations across the 50 U.S. states, 10 Canadian provinces and 18 other countries in addition to various nuclear consulting efforts. He has published more than 90 UFO papers and has appeared on hundreds of radio and TV programs, including three appearances on Larry King (2007 and 2008) and in several documentaries.

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Find out what's got the industry buzzing at the many complimentary sessions that are designed to keep attendees in the loop. This year's topics include a diversity of great discussions:

- Advanced Fabrication Instruction Exchange Between Design and Manufacturing: IPC-2581B Model
- U.S. Federal Funding Opportunities: Grant Programs and Public-Private Partnerships for R&D and Advanced Manufacturing
- California Chemicals Regulations
- PERM Discusses Pb-free—Are we there yet? (Panel Discussion)
- Electronic Technology Roadmaps
- IPC Worldwide Events 2015–2016
- More!

For a full listing of Buzz Sessions, [click here](#).

EMS and PCB Management Meetings

Designed to help industry members become better leaders, management meetings at IPC APEX EXPO 2015 offer exclusive learning and networking opportunities with senior-level managers and executives of PCB fabricators and their suppliers. The management program

meetings address issues related to improving executive decision-making in the industry, focusing on market trends, customer requirements and the economy.

EMS Management Council Meeting—Executive Level

Monday, February 23, 2015

7:15 a.m. (welcome breakfast) to 5:30 p.m.

- For a complete agenda, [click here](#).

PCB Supply Chain Leadership Meeting—Executive Level

Monday, February 23, 2015

7:15 a.m. (welcome breakfast) to 5:30 p.m.

- For a complete agenda, [click here](#).

IPC APEX EXPO 2015 Technical Conference

Recognized worldwide as the most selective in the world, the IPC APEX EXPO 2015 [technical conference](#) will present new research and innovations from experts in the areas of board fabrication and design, electronics assembly and test. Course moderators are carefully selected from within the electronics industry community.

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Professional Development Courses Sunday and Monday, February 22–23 Thursday, February 26

Learn about the latest in design, lead-free technologies, materials, process improvement, solder joint reliability and more at IPC APEX EXPO 2015. Choose courses by general topics to help you focus on the sessions that best meet your professional needs. This year's tracks include:

- Assembly processes for lead-free and tin-lead
- Cleaning/coating/contamination
- Design
- Emerging technologies
- PCB fabrication and materials
- Quality, Reliability and Test
- More! [Click here](#) for the complete Agenda Planner.



The PCB List—Find out what it's all about in the I-Connect007 booth!

Brought to you by PCB007, [The PCB List](#) is the world's most comprehensive online directory of printed circuit manufacturers, anywhere. Buyers, specifiers, designers and others looking for a PCB fabricator benefit from the intuitive navigation, detailed search capability, and global reach of The PCB List. With a Showcase listing, a PCB fabricator can create a neat, organized presentation that puts all pertinent information at a potential customer's fingertips.

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Real Time with...

This year, I-Connect007 and the Real Time with...program return to sunny San Diego to bring our readers video coverage of IPC APEX EXPO 2015. Expect to see our team of editors, guest editors, and videographers roaming the show floor throughout the event, to capture one-on-one interviews with the industry's top technologists, engineers, and business leaders—as the action happens!

Visit [Real Time with...](#) during the show for updated information about IPC APEX EXPO 2015.





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at the IPC APEX EXPO, February 24-26, 2015



PCB007
News

TOP TEN

News Highlights from PCB007 this Month

1 **Advanced Boards Drive Demand for AOI Equipment**

Currently, AOI is chiefly applied to PCB and TFT-LCD industries. However, for China, the penetration of AOI in the two industries is still rather low, with only 20 to 30% of production lines in the PCB industry equipped with AOI.

2 **Cicor Improves Financial Flexibility with New Financing**

The arranged credit facility with a consortium of banks, led by Commerzbank Aktiengesellschaft, has a duration of three years, with two extension options of one additional year each, therefore running for a maximum term of five years.

3 **HKPCA & IPC Show Sets New Attendance Records**

This year's show again broke all previous records for participation, making it not just the largest ever in the 13-year history of the event, but the largest trade show in the entire world for the PCB and electronic assembly industry.

4 **Omni Circuit Boards Signs R&D Agreement with D-Wave**

Omni Circuit Boards Ltd. announced today the signing of a research and development agreement with D-Wave Systems Inc., the first commercial quantum computing company, in support of the further advancement of aluminum trace printed circuit boards (Al-PCB) for quantum computing applications.

5 TTM Receives Foreign Approvals to Acquire Viasystems

TTM Technologies, Inc. has received the approvals of the Ministry of Commerce of the People's Republic of China, the Federal Cartel Office of Germany, and the Estonian Competition Authority to proceed with the acquisition of Viasystems Group, Inc.

6 Saturn Electronics Opens Doors for PCB Tours

Saturn Electronics is opening its doors to customers this January as part of its "Open House" initiative, where PCB experts from the company will be on hand to answer any questions regarding the fabrication process of the PCB and Saturn Electronics' capabilities at its Romulus, Michigan facility.

7 IPC: N.A. PCB Order Growth Bolsters Book-to-Bill Ratio

"Although PCB sales in North American continued below last year's level in November, orders again came in above last year," said Sharon Starr, IPC's director of market research. "Strong orders in the fourth quarter have driven the book-to-bill ratio into positive territory, which offers hope that year-on-year PCB sales growth will turn positive in 2015."

8 AT&S Offers Embedded Power Electronics

Due to constant technology development and strong partnerships, AT&S has achieved outstanding results in the field of power electronics. This solution provides a significant increase in efficiency and performance for industrial and automotive applications.

9 MFLEX Concludes Solid Q4 Financial Results

Reza Meshgin, Chief Executive Officer of MFLEX, commented, "We generated another quarter of solid profitability during the December quarter. Strong demand, including continued contribution from our group of eight newer customers, supported an anticipated 21 percent sequential increase in net sales."

10 IPC Establishes Local Presence in Korea

The Standards Committee of IPC Korea will help members to develop and revise global standards, educate and train workers, provide technology consultation, hold technology development forums, standardize electronics terminologies in Korean, and hold networking events. This will help establish a collaborative relationship among the government, electronics industry, and academia.

For the latest PCB news and information, visit: PCB007.com



EVENTS



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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](#).

SMTA Pan Pacific 2015

February 2–5, 2015
Kauai, Hawaii, USA

SEMICON Korea 2015

February 4–6, 2015
Seoul, Korea

MEDIX 2015

February 4–6, 2015
Osaka, Japan

LED Korea 2015

February 4–6, 2015
Seoul, Korea

EIPC Winter Conference

February 5–6, 2015
Munich, Germany

Energy Innovation Summit

February 9–11, 2015
Washington D.C., USA

MD&M West

February 10–12, 2015
Anaheim, California, USA

2015 Flex Conference

February 23–26, 2015
Monterey, California, USA

IPC APEX EXPO 2015

February 22–26, 2015
San Diego, California, USA

FPD China 2015

March 17–19, 2015
Shanghai, China



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Coming Soon to The PCB Magazine:

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March:
Materials
(Plus: IPC APEX
EXPO Coverage!)

April:
HDI

May:
Plating & Etching