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SURFACE FINISHES

Characteristics of EPIG Deposits for Fine-Line Applications

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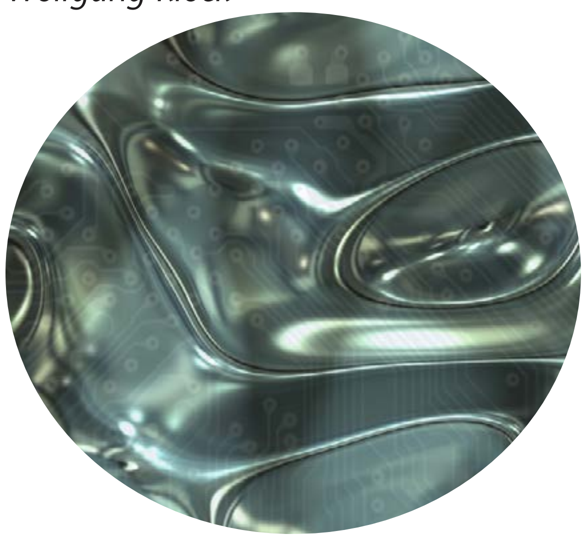
Surface Finishes

This month, experts from Uyemura, Epec Engineered Technologies, and Fischer Technology bring you in-depth coverage of surface finishes, including their capabilities and limitations. Plus, event coverage from our *Real Time with...* booth at productronica 2013 and images from the show floor in Munich, Germany.



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Surface Finishes

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Printed Electronics Update

by Ray Rasmussen
I-CONNECT007

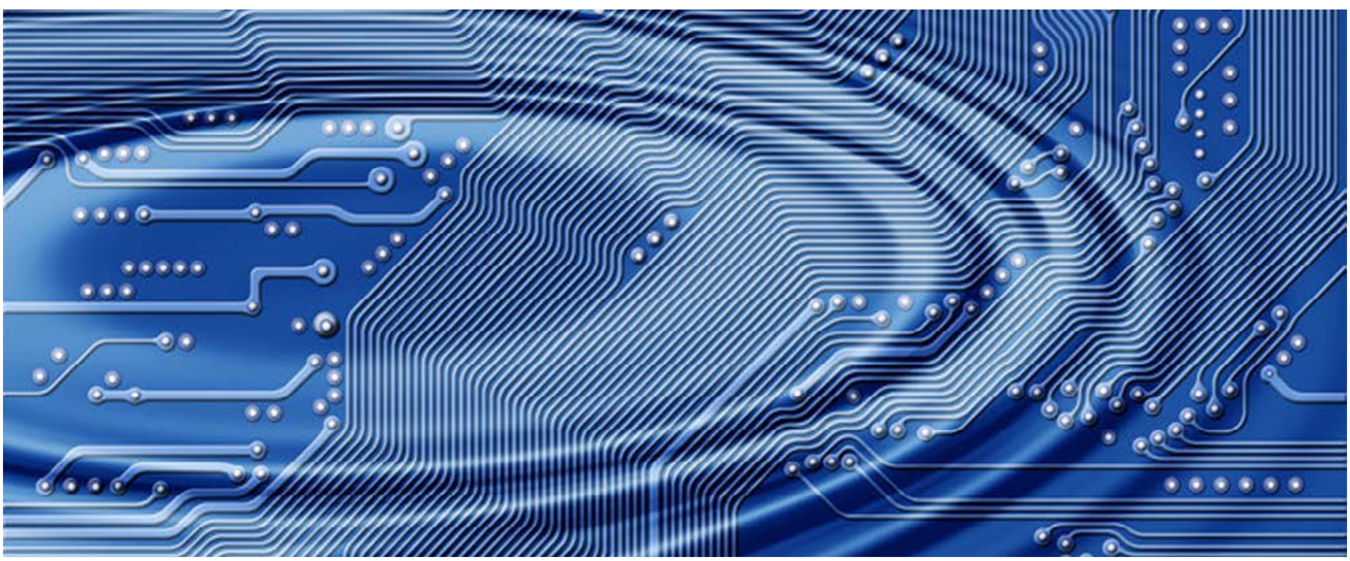
At IDtechEx this year in Santa Clara, California, I heard something for the first time: Several presenters said that they had replaced their PCBs with printed electronics. One of them was Multek (Flextronics).

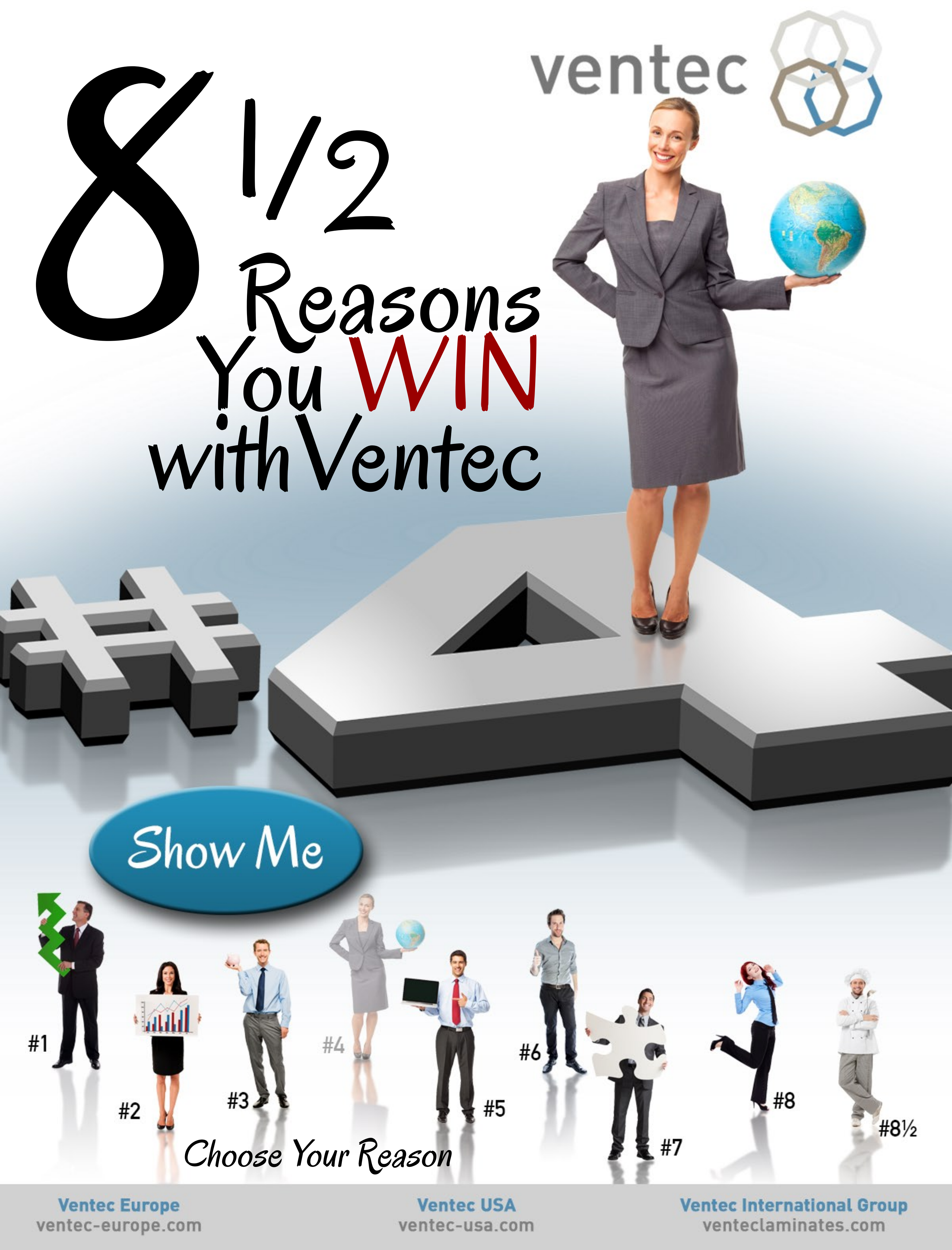
When people talk about PE opportunities, they almost always focus on new markets and how PE is an enabling technology that allows electronics to be added to just about any product out there. In fact, there are some who suggest that it's possible to connect over a trillion products through the use of PE technologies, when they talk about The Internet of Things. It's really astounding.

Flextronics/Multek gave an interesting presentation about their efforts in PE. They're moving quite quickly into materials, thanks to their acquisition of Sheldahl and their flex materials. And as I mentioned, they are already replacing PCBs with PE circuits.

PE for EMS

A few years ago, I invited Matt Timm, CEO of Soligie, to keynote an IPC conference on printed electronics that I was emceeing. Soligie is a PE contract manufacturer: EMS for the PE industry. I had invited him to talk about the current status and prospects for the future. Timm spent a lot of time talking about the hype curve and how the industry was starting to come down the backside of the curve, which was the more realistic state of the industry. Still exciting, but the reality was that PE technologies were going to take longer than the pundits had been espousing. He was in the trenches and had a good perspective on things. Something he said to me offline, which I found quite interesting, was that his biggest concern with our industry was the giant EMS providers like Flextronics who, when they figured out the opportunity, would eat his lunch. Well, I think they're starting to do just that. It's still a specialty market for them but it's going to grow really fast. They already have the customers. Now, they just need to match the PE product with the right customer and application. The customers want it. On the EMS side, the opportunities are almost endless. They do everything needed for PE in-house, on their own, wherever the customer is located. They can mix and match conventional technologies with emerging PE options when and where needed. They're in a great position to dominate this market in fairly short order.

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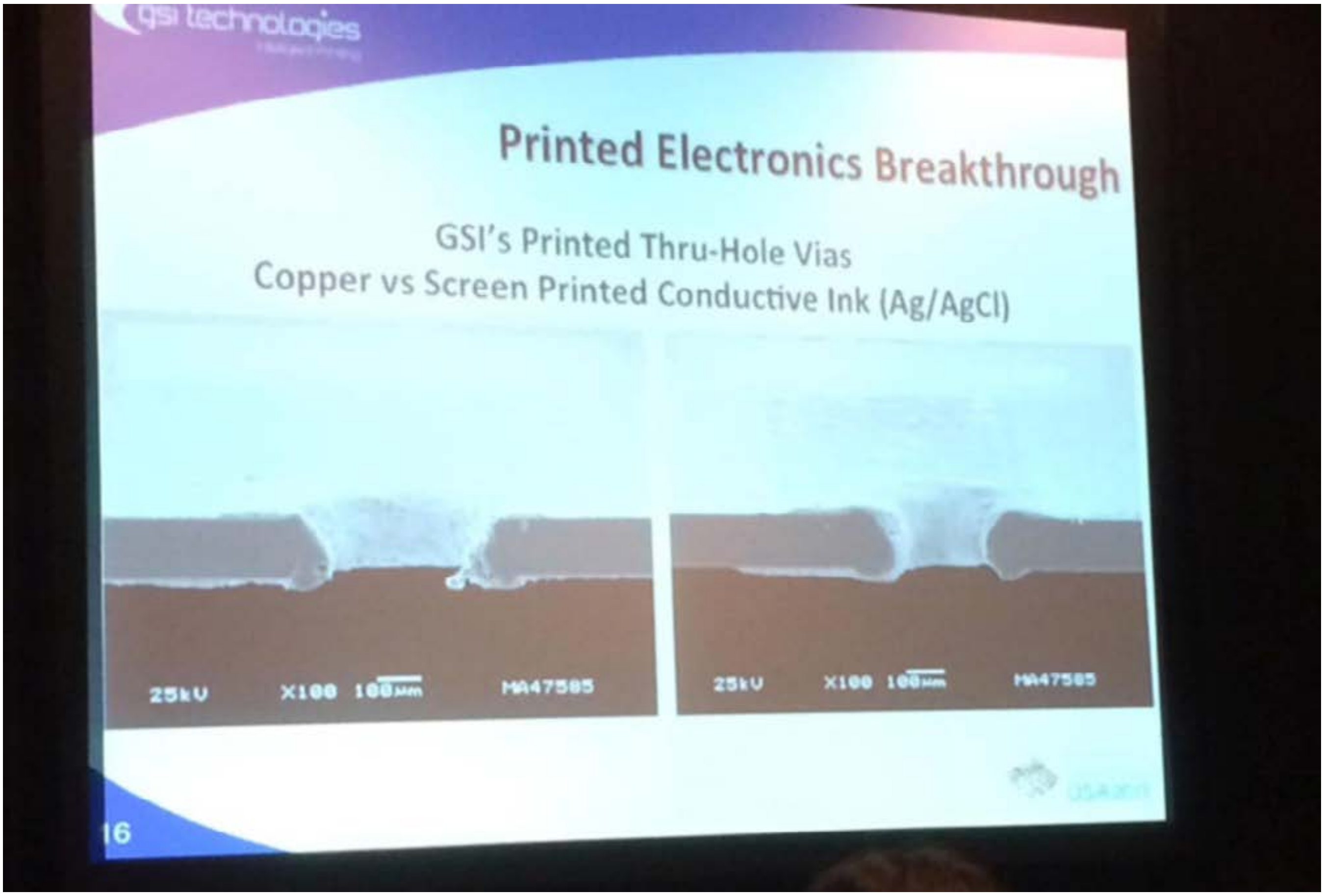

Figure 1: A slide from GSI's presentation on printed electronics.

PE for PCB

I ran into John Andresakis from Oak-Mitsui who, like me, has a keen interest in printed electronics. As we discussed some of the technologies and presentations we saw at the show, I suggested that we need an annual technical benchmark to show the progress of the PE materials and capabilities as they relate to PCB technology. It would be important for the industry to know how rapidly the PE capabilities are advancing. Certainly, the most obvious target for PE is the flex circuit industry. Flex PCB suppliers are already selling their latest materials at PE shows. Lots of companies are selling materials into this market. Conductive inks are everywhere and they're getting better and better every year. It won't be long before they perform like copper; then, watch out!

Figure 1 is a slide from GSI Technologies touting their "printed thru-hole vias." GSI was a printing company that has made the jump into printed electronics.

In a presentation from PragmatIC, the CEO caught my attention. Basically, he said that the closer they get to free (referring to the cost of their product, which is printed memory), the larger the market gets. I've heard these kinds of statements before, but the way he put it made a lot of sense to me. At a higher price point, the market is limited. The higher you go, the smaller the market. If you go high enough, you reach the costs of traditional electronics, which is the market we're all very familiar with. I get all this. It's logical and makes sense. Very few of our manufacturers are looking for ways to reduce the cost of their boards for their customers. Typically, we fight every price change and try to not leave any money on the table. The problem with that thinking is that it closes the door on a ton of potential that the

PE guys have grabbed hold of. That's the way they think.

Driving down cost as quickly as possible to expand the market makes a lot of sense to them. You could say that the Chinese, and in particular, Foxconn have also grabbed that concept by building boards and assemblies in an environment that allows them to dramatically reduce costs; this has opened up a much larger market for electronics than would have otherwise existed. Now, most of the world can afford electronic products, which were mainly sold in developed countries. As a result, all boats rise. More electronic gadgets require more electronic infrastructure, which creates more jobs which then provides more income and more buying power, etc. Now, PE takes this cost reduction to a whole new level. In just a few years everyone, everywhere, will have access to most of the technologies out there and printed electronics will make that happen.

As I mentioned last month, in a recent assembly industry technology survey, printed electronics was the topic of greatest interest. Although not surprising to me, it does indicate that our industries are finally waking up. And as I said earlier, the EMS companies are in a prime position to leverage the capabilities of PE technologies for their customers. My biggest concern is with the PCB fabricators. There is both a great opportunity and an ultimate end-game for many. I'm not sure why there aren't many more fabricators walking a show like IDtechEx. I only saw a few (Sunstone, Viasystems, Multek). Maybe I'm way off base, but I don't think so. **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.

VIDEO INTERVIEW

Global Outlook on Electronic Chemicals Market

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Chris Hrusovsky, Electronic Chemicals global business manager for OM Group, gives his perspective on the world market for electronic chemicals and discusses how product innovation and technical support have made them successful.

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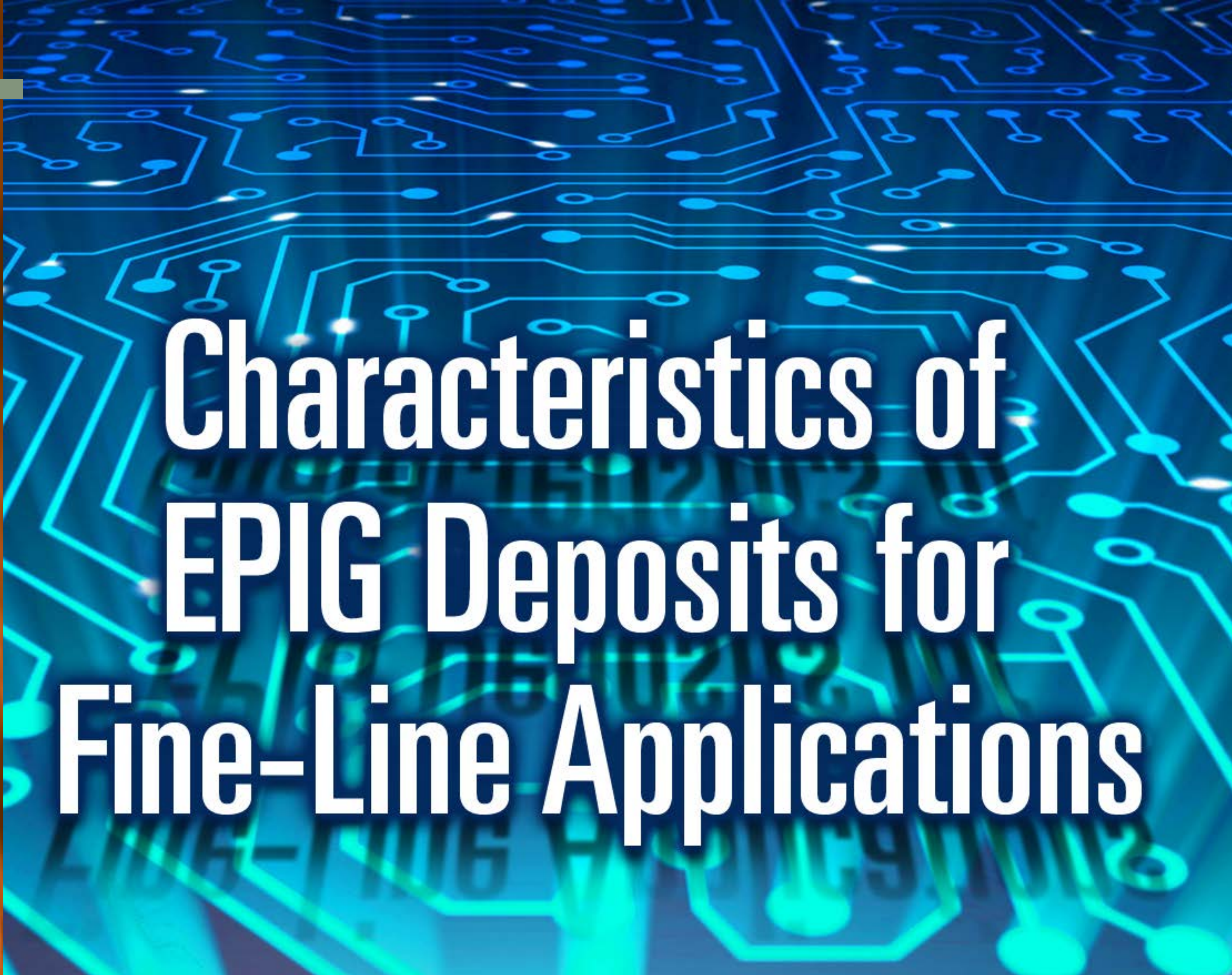
Characteristics of EPIG Deposits for Fine-Line Applications



by Shigeo Hashimoto, et al.[1]

As previously published by SMTA in the proceedings of SMTA International 2013.

Abstract

The ability to plate fine patterns, the solder joint reliability (SJR) and the wire bonding reliability (WBR) of the electroless Pd/Au (EPIG) deposit were compared with the electroless Ni-P/Pd/Au (ENEPIG) deposit.

SJR was evaluated by high-speed shear test (HSS) when comparing Sn-3.0Ag-0.5Cu with Sn-1.2Ag-0.5Cu-0.05Ni as the composition of the solder ball. When using Sn-1.2Ag-0.5Cu-0.05Ni as the solder ball for EPIG film, the uniform alloy layer was formed and SJR became excellent.

EPIG deposits with thicker Pd had good WBR because the Pd layer prevented Cu diffusion to the top of Au surface after heat treatment. And when Au thickness of EPIG deposit was thicker, WBR became better because the ratio of Pd on the top surface was kept lower after heat treatment.

On the other hand, WBR after heat treatment was improved by applying plasma treatment on Au surface.

Introduction

In recent years, the electronic devices, such as a smartphone and a tablet PC, have been miniaturized. Therefore, CSP (chip size package) used inside the electronic devices have also been miniaturized, and the space of the wiring lines have become narrower every year. Some of latest packages have the space of the wiring line of 15 µm or less. At that time, if electroless Ni-P

(EN) film will be 5–6 μm as the conventional ENEPIG process, the space of the wiring line became 5 μm or less. This will indicate that there is the risk of short-circuit between the wiring lines. In order to prevent this problem, thin EN process or EN free process (EPIG) will be suggested. If using thin EN or EPIG process, it's possible to make the plating process time short. In addition, EPIG process may have the possibility for high-frequency devices and the solution for Ni allergy problem.

On the other hand, CSP have mainly two kinds of the joining method with the substrate or IC chip, which are wire bonding joining between IC chip and the packaged and some type of solder joint. Therefore, for the plating it's necessary for EPIG process to focus on SJR, WBR and the pattern ability.

In this paper, we studied these characteristics of EPIG deposits, compared with ENEPIG deposits.

Experiment and Results

The coupons used in this study consisted of a copper-clad laminated substrate which was copper plated to a thickness of 20 μm using an acid copper electroplating process. For SJR tests, the copper-plated substrate was coated with solder mask and imaged to form 0.25 mm diameter solder ball pads. Furthermore, the substrate of the copper pattern with 15 μm space of the wiring line was used for evaluating of the pattern ability. Each substrate was plated with EPIG and ENEPIG by using plating chemicals commercially available from C. Uyemura & Co., Ltd.

As the solder ball for the evaluation of SJR, 0.3 mm Φ of Sn-3.0Ag-0.5Cu (M705) 0.3 mm Φ of Sn-1.2Ag-0.5Cu-0.05Ni (LF35) were used. The reflow profile with the top temperature of 260°C was applied for mounting the solder ball as shown in Figure 1. SJR was measured by HSS test (Dage 4000HS/Dage) as shown in Table 3. The condition of heat treatment after mounting the solder ball was done for 300 hours at

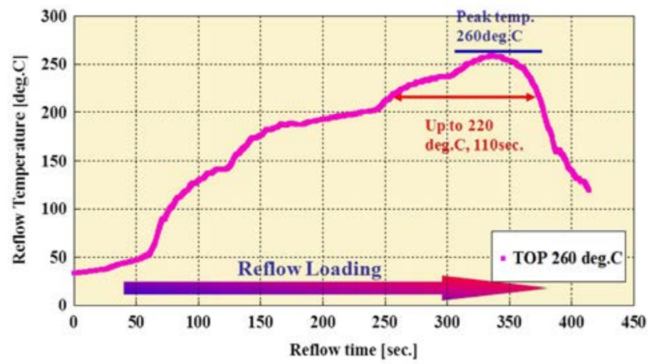


Figure 1: Reflow profile.

Process	Chemical	Temp.	Time
Cleaner	Mild alkaline	50 degC	5 min
Soft etching	15g/L mono per.	30 degC	2 min
Acid rinse	10% Sulfuric acid	R.T.	1 min
Pre-dipping	0.4% Sulfuric acid	R.T.	1 min
Activator	Palladium-type	30 degC	1.5 min
Post-dip	acidic type	50 degC	0.5 min
Electroless Pd	Pd-P	60 degC	5 min (0.05um)
			10 min (0.10um)
			20 min (0.20um)
Electroless Au	Mixed reaction	78 degC	6 min (0.05um)
			12 min (0.10um)
			24 min (0.20um)
			36 min (0.30um)

The target thicknesses were Pd = 0.05, 0.1, 0.2 μm and Au = 0.05, 0.1, 0.2, 0.3 μm

Table 1: The EPIG plating process.

Process	Chemical	Temp.	Time
Cleaner	Mild alkaline	50 degC	5 min
Soft etching	100g/L SPS	25 degC	1 min
Acid rinse	10% Sulfuric acid	R.T.	1 min
Pre-dipping	3% Sulfuric acid	R.T.	1 min
Activator	Palladium-type	30 degC	2 min
Electroless Ni-P	Mid phos Ni-P	80 degC	30 min
Electroless Pd	Pd-P	50 degC	5 min (0.05um)
			10 min (0.10um)
			20 min (0.20um)
			30 min (0.30um)
Electroless Au	Mixed reaction	78 degC	12 min

The target thicknesses were Ni = 6 μm, Pd = 0.1 μm and Au = 0.05, 0.1, 0.2, 0.3 μm

Table 2: The ENEPIG Plating Process.

Equipment	TPT HB16 (semi-auto)
Capillary	B1014-51-18-12 (PECO)
Wire	1.0mils gold
Temp.	150deg.C
Step	0.7mm
1st bonding conditions	Ultra sonic=250mW Time=200msec Force=25g
2nd bonding conditions	Ultra sonic=250mW Time=50msec Force=50g
Pull test equipment	Dage #4000
Pull speed	170um/sec

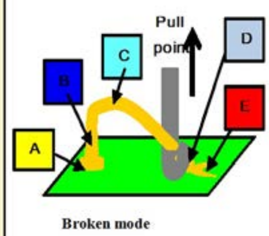


Figure 2: Wire bonding conditions.

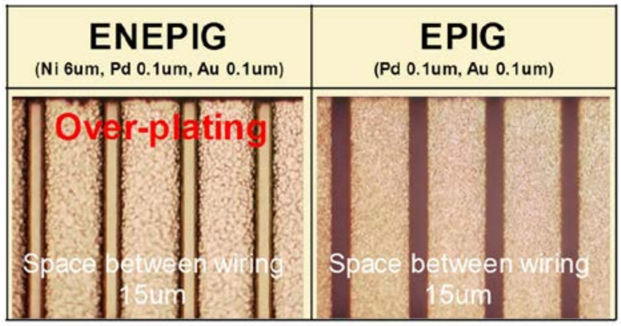


Figure 3: Over-plating of EPIG and ENEPIG.

150°C. The oven (high-temp oven PHH-101/ESPEC) was used for heat treatment. The cross section image of IMC after mounting the solder ball was observed by FE-SEM (Ultra55/Carl Zeiss) after polishing by cross section polisher (CP) (SM-09010 /JEOL). The intermetallic (IMC) layer was analyzed by EDS (AXS/ Bruker).

WBR was evaluated by wire bonding (HB16/TPT) and pull test (Dage 4000/Dage) as shown in Figure 2. The condition of heat treatment for WBR was done for 16 hours at 175°C.

The element analysis for each film was measured by Auger electron spectroscopy (AES) (9500F/JEOL). The condition of AES was shown in Table 4.

The plasma test after heat treatment was performed by plasma cleaner (PC-1100/SAMCO). The condition of the plasma treatment was shown in Table 5.

Pattern Ability for EPIG Deposits

Figure 3 shows the comparison of pattern ability between ENEPIG process and EPIG process when using the substrate with15 μm as the space of wiring lines. Although ENEPIG process had over-plating in the space of the wiring line, no over-plating was observed for the EPIG process.

Solder Joint Reliability

For EPIG process and ENEPIG process, SJR with the film as plated (As-plated) and with heat treatment after mounting the solder ball (300 hrs HT) were evaluated by HSS test as shown in Figure 4. In this figure, M705 was used as the solder ball. The influence of Pd thickness was not confirmed within 0.05–0.2 μm. When comparing the film of as-plated, the broken energies of ENEPIG film were better

Reflow equipment	Tamura TMR-15-22LH
Solder ball	SAC305 (M705) Sn-1.2Ag-0.5Cu-Ni (LF35)
Solder diameter	0.30mmφ
Pad size	0.25mmφ
Flux	529D-1
Reflow conditions	260 deg.C, 1 times
HSS test equipment	4000HS (Dage)
HSS speed	1000mm/sec

Table 3: HSS Test Conditions.

Wide scan		Depth profile	
Ep	: 10keV	Ep	: 10keV
Ip	: 4×10^{-8}A	Ip	: 4×10^{-9}A
Area	: 120*120 (μm2)	Area	: 120*120 (μm2)
Tilting Angle	: 30°	Tilting Angle	: 30°
		Aperture size	: 4

Table 4: AES Conditions.

Process gas	: Ar
Flow rate	: 30sccm
Power	: 500W
Time	: 1min

Table 5: Plasma Conditions.

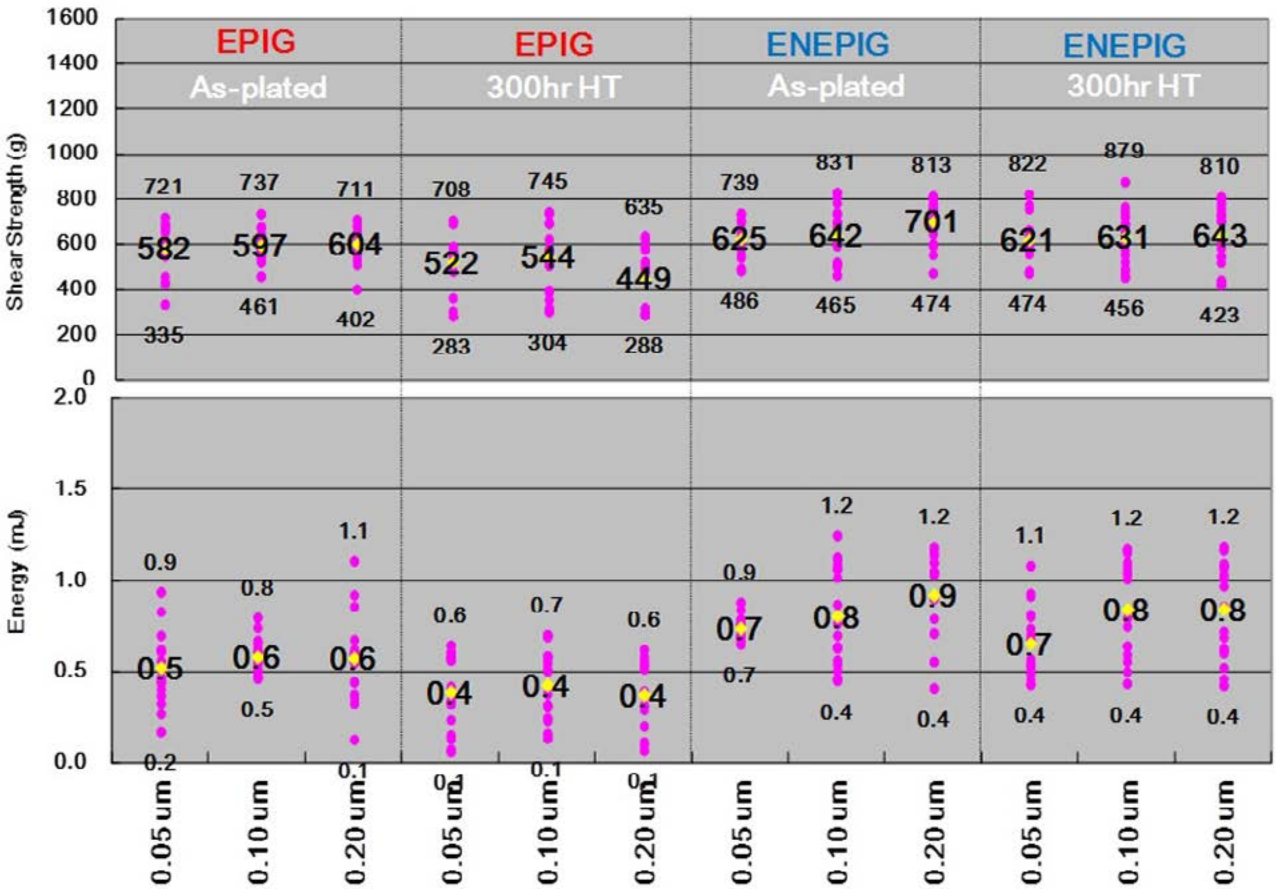


Figure 4: HSS results with M705 as the solder ball; EPIG (Pd 0.05–0.2 µm, Au 0.1 µm) and ENEPIG (Ni-P 6 µm, Pd 0.05–0.2 µm, Au 0.1 µm).

than that of EPIG. The broken energy of EPIG film after heat treatment became poorer, compared with as-plated sample. On the other hand, if using ENEPIG process, the broken energy of HSS was kept even if there was heat treatment.

The cross-section image of the IMC was observed to consider the cause of HSS results. When using EPIG film or ENEPIG film with Pd thickness of 0.1 µm and with Au thickness of 0.1 µm, the observation of IMC and the analysis of IMC composition by EDS were shown in Fig. 5. From the results of EDS, when using EPIG film, Cu_6Sn_5 was formed as layer 1 and Cu_3Sn was formed near Cu layer as layer 2. On the other hand, when using ENEPIG film, $(Cu, Ni)_6Sn_5$ was formed as layer 1 and $Ni+Ni_3P$ was formed near Ni-P layer as layer 2[2,3,4]. It was considered that HSS results of ENEPIG were better for As-plated because layer 1 of ENEPIG film was more uniform than that of EPIG film.

When comparing the film of 300hrs HT, layer 2 of EPIG became thicker significantly because Sn was supplied from the solder phase more and more by heat treatment. And layer 1 became thicker also. It was considered that these thicker IMC will cause poor broken energy of HSS.

On the other hand, the thickness of layer 1 and 2 was not changed for ENEPIG film. It was considered that $Ni+Ni_3P$ was thinner as layer 2 because $(Cu, Ni)_6Sn_5$ was formed by the existence of Cu in the solder ball of M705 and this IMC inhibited the growth of layer 2. Moreover, because layer 1 will be dissolved into the solder phase gradually, thinner layer 1 was kept[2]. Therefore, the broken energies of ENEPIG film were better even if there was heat treatment.

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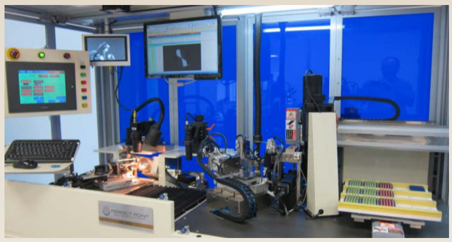

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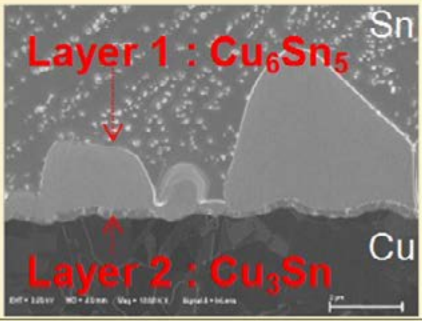
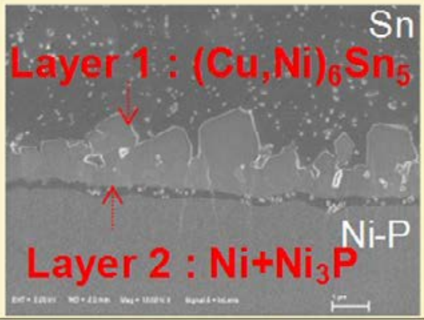
M705	EPIG		ENEPIG	
As-plated				

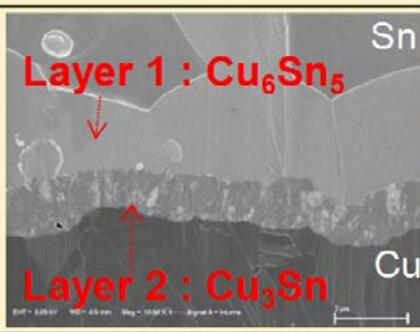


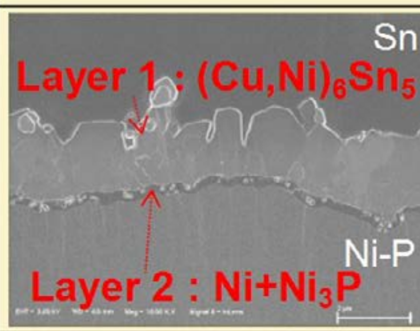


M705 As-plated	EPIG Layer 1	EPIG Layer 2	ENEPIG Layer 1	ENEPIG Layer 2
Ni	0.0	0.0	21.1	74.7
P	0.0	0.0	1.3	17.0
Cu	53.1	62.7	38.7	4.3
Pd	0.0	0.0	0.2	0.3
Sn	46.9	37.3	38.7	3.5

Figure 5: IMC observation and analysis of IMC composition by EDS with M705; EPIG (Pd 0.1 µm, Au 0.1 µm) and ENEPIG (Ni-P 6 µm, Pd 0.1 µm, Au 0.1 µm) as plated.

M705	EPIG		ENEPIG	
300 hours				





M705 300 hours	EPIG Layer 1	EPIG Layer 2	ENEPIG Layer 1	ENEPIG Layer 2
Ni	0.0	0.0	17.2	68.7
P	0.0	0.0	0.1	28.7
Cu	56.1	77.2	35.1	0.4
Pd	0.0	0.0	0.6	0.0
Sn	43.9	22.8	47.3	2.1

Figure 6: IMC observation and analysis of IMC composition by EDS with M705; EPIG (Pd 0.1 µm, Au 0.1 µm) and ENEPIG (Ni-P 6 µm, Pd 0.1 µm, Au 0.1 µm) after heat treatment.

When using LF35 as the solder ball, the result of HSS was shown in Figure 7. And the observation of IMC and the analysis of IMC composition by EDS were shown in Figure 8 and Figure 9.

The broken energy of HSS for EPIG film was better, compared with the result with M705. From the results of EDS shown in Figure 7, $(Cu,Ni)_6Sn_5$ was formed as layer 1 and Cu_3Sn was formed as layer 2. Ni was supplied for the solder ball of LF35. It was considered that layer 1 became uniform and thinner because its Ni inhibited the growth of layer 1. Thinner and uniform layer 1 will result in better broken energy of HSS. Layer 1 became thicker after heat treatment, but layer 2 still kept thinner. It was considered that $(Cu, Ni)_6Sn_5$ inhibited the growth of layer 2 by making the supply of Sn slower into layer 2. As the results of IMC formation, the broken energy of 300hrs HT was worse than that of as-plated for EPIG film.

On the other hand, the result of HSS for ENEPIG film was similar with that of M705 regardless of as-plated sample and 300hrs HT sample. It was considered that similar tendency was observed because similar IMC was formed even if the different type of the solder ball was used.

From these results, it will be possible that SJR of EPIG film was significantly improved by using LF35 as the solder ball. However, there will be possibility that SJR after long term heat treatment become worse. It's necessary to confirm the influence of longer heat treatment.

Gold Wire Bonding

The strength and failure mode of wire pull test for as-plated sample of an EPIG and ENEPIG film were shown in Figure 10 and Figure

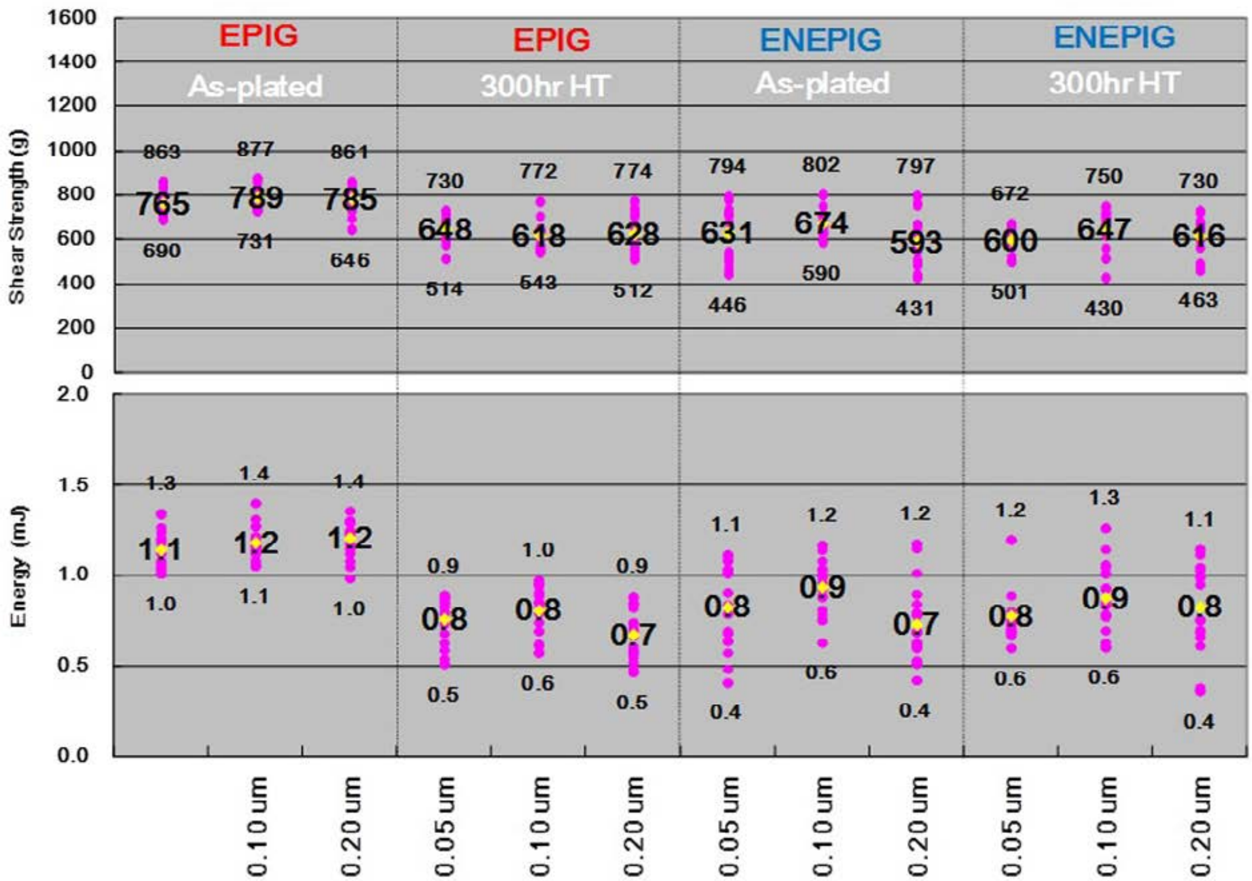
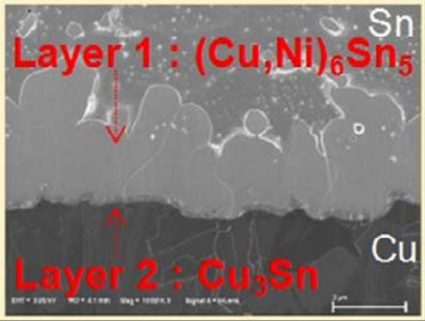
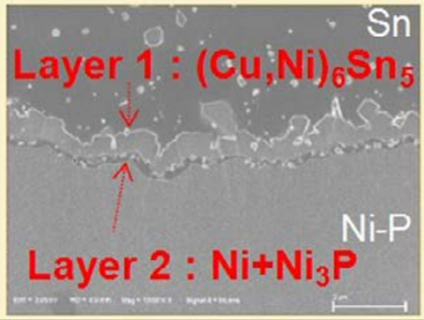


Figure 7: HSS result with LF35 as the solder ball; EPIG (Pd 0.05–0.2 μm, Au 0.1 μm) and ENEPIG (Ni-P 6 μm, Pd 0.05–0.2 μm, Au 0.1 μm).

LF35	EPIG	ENEPIG
As-plated		



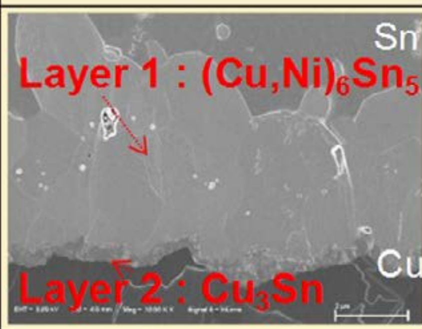
	Layer 1	Layer 2
Ni	5.3	0.4
P	0.0	0.0
Cu	54.6	77.7
Pd	0.0	0.0
Sn	40.1	21.9



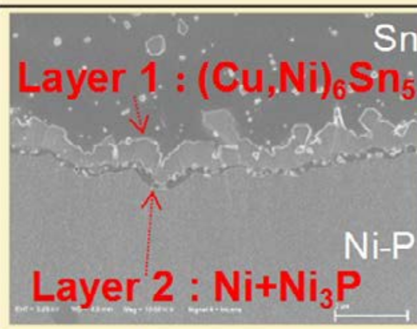
	Layer 1	Layer 2
Ni	33.2	75.7
P	1.2	18.3
Cu	30.7	3.6
Pd	0.3	0.2
Sn	34.6	2.2

Figure 8: IMC observation and analysis of IMC composition by EDS with LF35; EPIG (Pd 0.1 μm, Au 0.1 μm) and ENEPIG (Ni-P 6 μm, Pd 0.1 μm, Au 0.1 μm) as plated.

LF35	EPIG	ENEPIG
300 hours		



	Layer 1	Layer 2
Ni	6.6	0.1
P	0.0	0.0
Cu	52.4	75.5
Pd	0.0	0.0
Sn	40.4	24.4



	Layer 1	Layer 2
Ni	20.2	66.5
P	0.1	24.3
Cu	32.8	0.5
Pd	0.5	0.1
Sn	46.4	8.6

Figure 9: IMC observation and analysis of IMC composition by EDS with LF35; EPIG (Pd 0.1 μm, Au 0.1 μm) and ENEPIG (Ni-P 6 μm, Pd 0.1 μm, Au 0.1 μm) after heat treatment.

12 while the results after heat treatment were shown in Figure 11 and Figure 13.

For the as-plated samples, wire pull test results of EPIG were not related to Pd deposit thickness, but became better a little as Au thickness increased.

For the sample after heat treatment for 16 hours at 175°C, wire pull results of EPIG film became worse, especially when Pd thickness was thinner. Also, the tendency was obvious that EPIG deposits with thicker Au had better WBR even if there was heat treatment.

On the other hand, when both Au and Pd thicknesses were thinner, ENEPIG film had better WBR even if there was heat treatment, compared with EPIG film.

For EPIG and ENEPIG deposits with Au

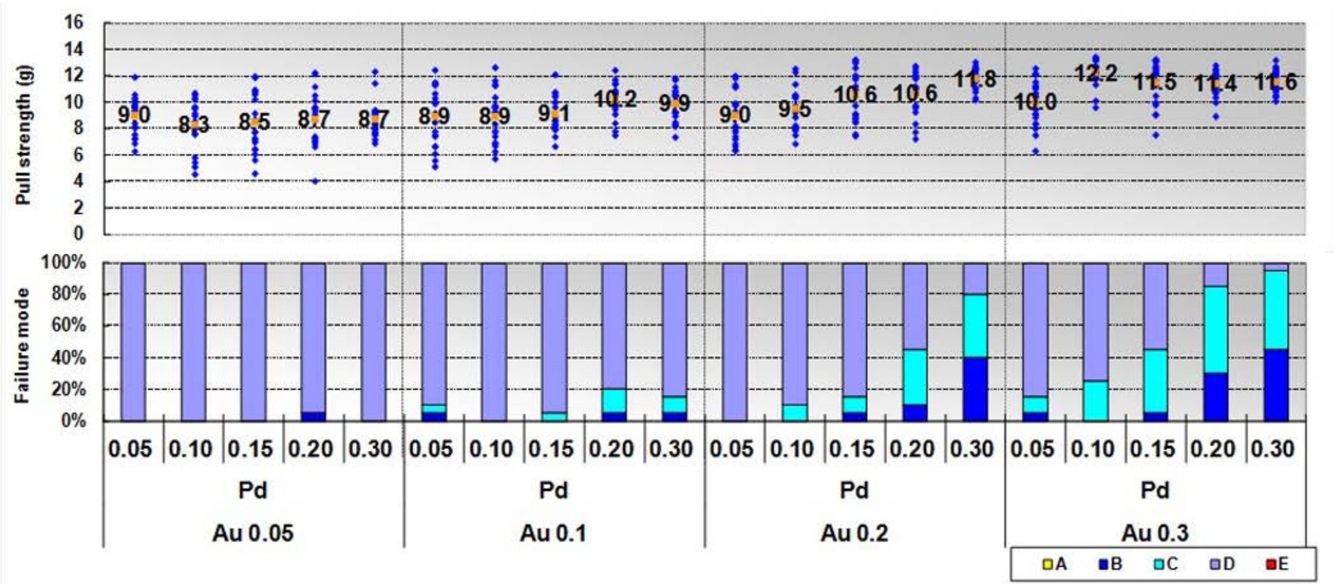


Figure 10: Wire pull test results; EPIG (Pd 0.05–0.3 μm, Au 0.05–0.3 μm) as-plated.

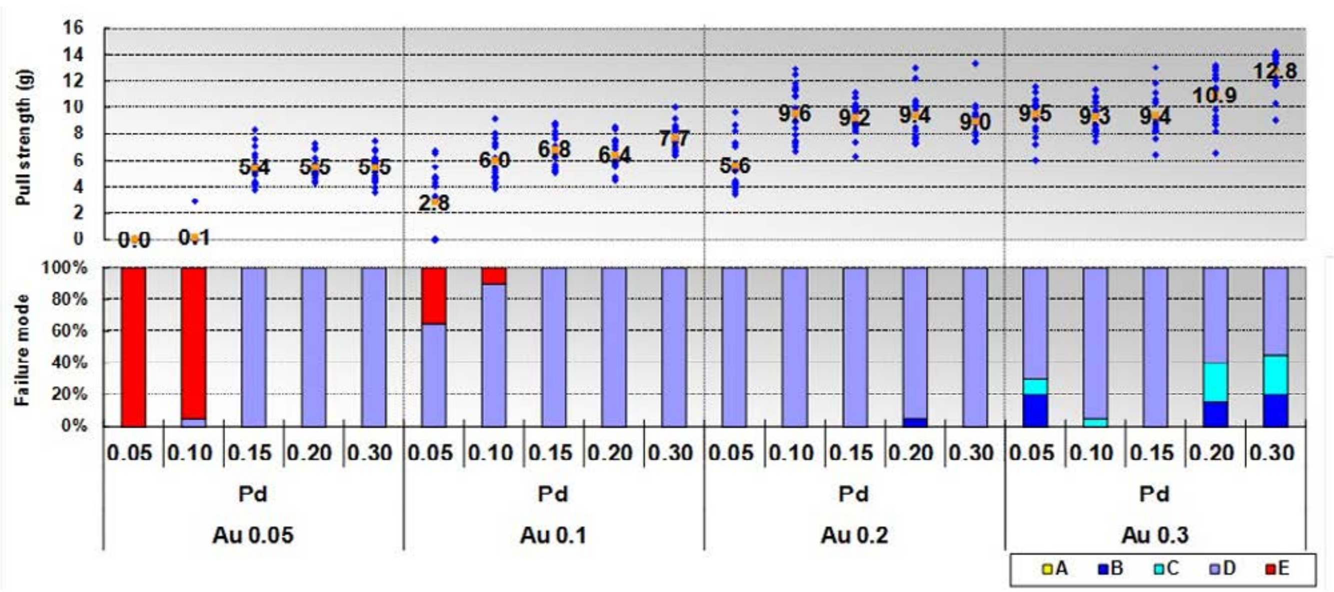


Figure 11: Wire pull test results; EPIG (Pd 0.05–0.3 μm, Au 0.05–0.3 μm) after heat treatment.

thickness of 0.1 µm and with Pd thickness of 0.1 µm, the results of wide scan and depth profile by AES were analyzed as shown in Figure 14 and Figure 15.

From the result of wide scan for EPIG film after heat treatment, the peak of Cu was detected, but no Cu peak was detected for ENEPIG film. It was considered that one of the factors, which EPIG film had poorer WBR after heat treatment, was Cu diffusion to the Au surface.

Also, the peak of Pd was detected for EPIG film and ENEPIG film after heat treatment. From the result of depth profile, it was observed that Pd exists in Au film layer fully. It was considered that the solid solution layer of Au and Pd was formed and this was second factor, when

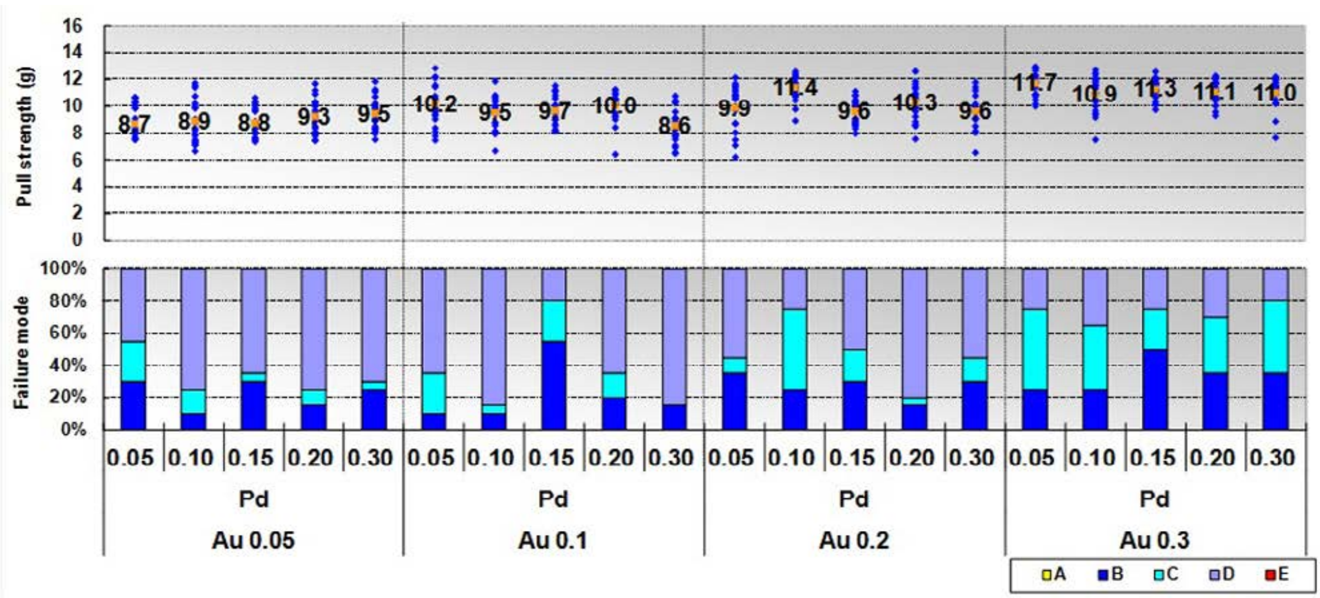


Figure 12: Wire pull test results; ENEPIG (Ni-P 6 µm, Pd 0.05–0.3 µm, Au 0.05–0.3 µm) as-plated.

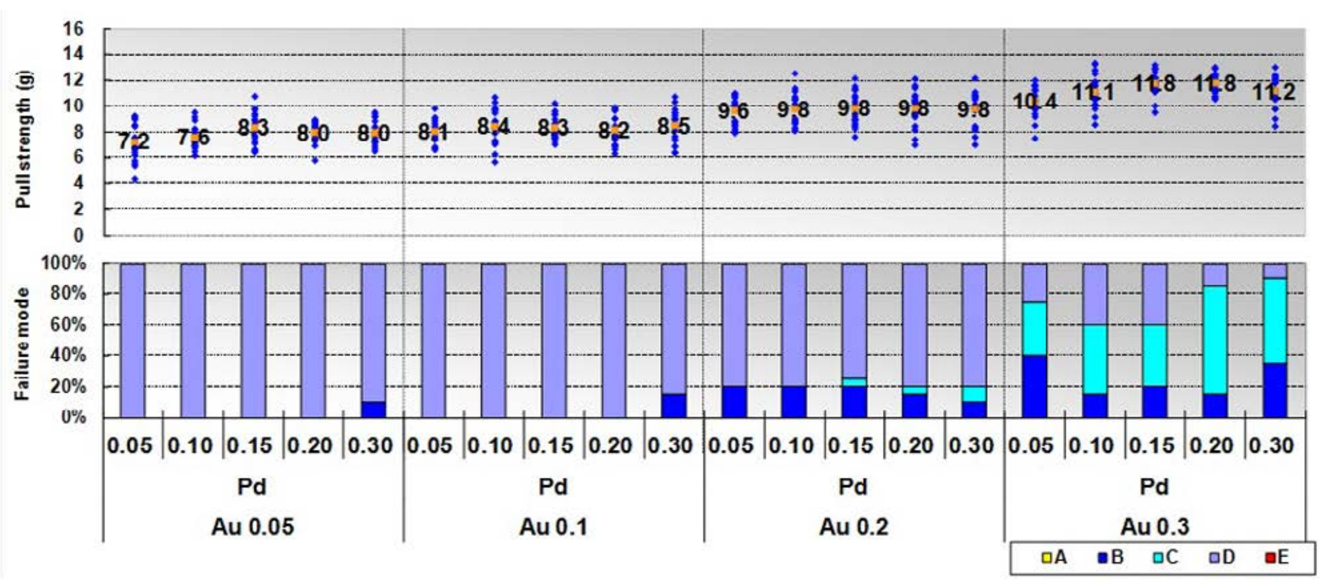


Figure 13: Wire pull test results; ENEPIG (Ni-P 6 µm, Pd 0.05–0.3 µm, 0.05–0.3 µm) after heat treatment.

poorer WBR was caused when Au and Pd thickness was thinner.

In order to keep WBR of the EPIG film after heat treatment, it was suggested that it will be necessary to prevent Cu diffusion and Pd diffusion.

For EPIG film, the effect of Pd and Au thickness was confirmed as shown in Figure 16 and 17 by using wide scan and depth profile of AES after heat treatment.

From the result of wide scan, the peak of Cu was detected when Pd film was thinner. Howev-

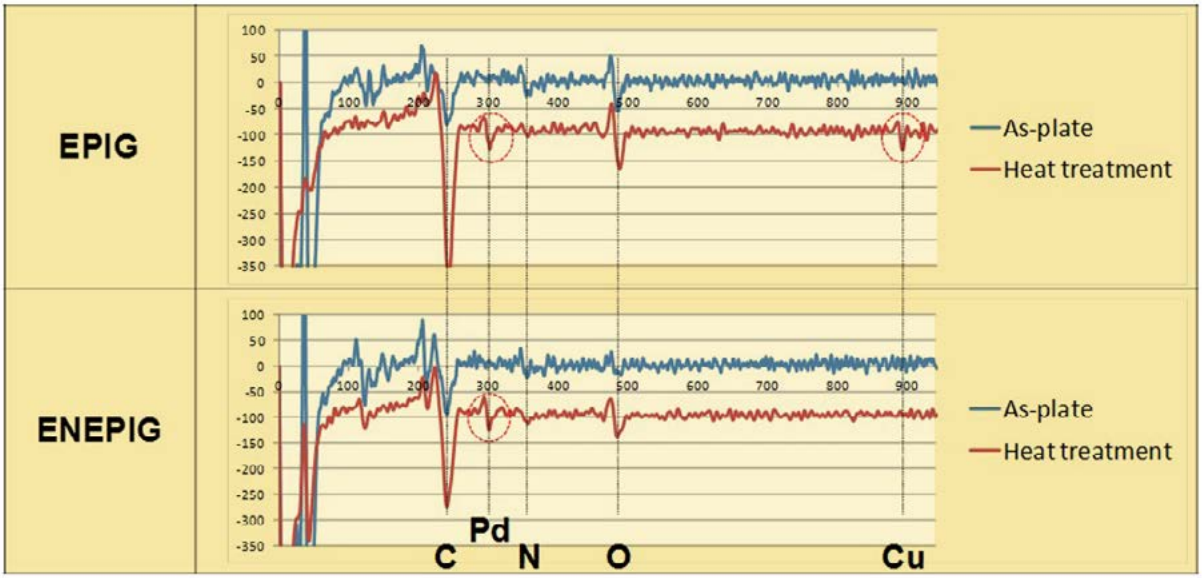


Figure 14: Wide scan results by AES; EPIG (Pd 0.1 μm, Au 0.1 μm), ENEPIG (Ni-P 6 μm, Pd 0.1 μm, Au 0.1 μm) as plated and with heat treatment.

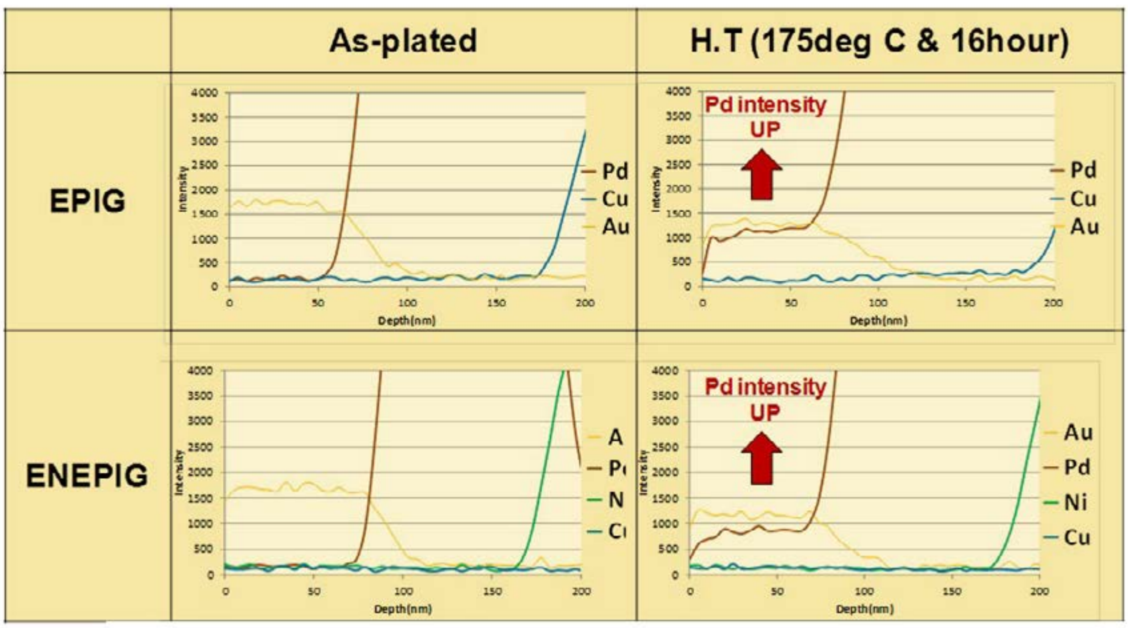


Figure 15: Depth profile results by AES; EPIG (Pd 0.1 μm, Au 0.1 μm), ENEPIG (Ni-P 6 μm, Pd 0.1 μm, Au 0.1 μm) as plated and with heat treatment.

er, no peak of Cu was detected when Pd thickness was thicker. Therefore, thicker Pd film was effective to prevent Cu diffusion to Au surface. And also the peak of Pd with thicker Au layer was weaker than that with thinner Au layer. From the results of depth profile, the ratio of Pd in Au layer with thicker Au layer was lower than that with thinner Au layer.

The ratio of Pd and Au intensity for the depth profile was plotted for every Pd and Au thickness as shown in Figure 18. The value of Au and Pd intensity used in this figure was that

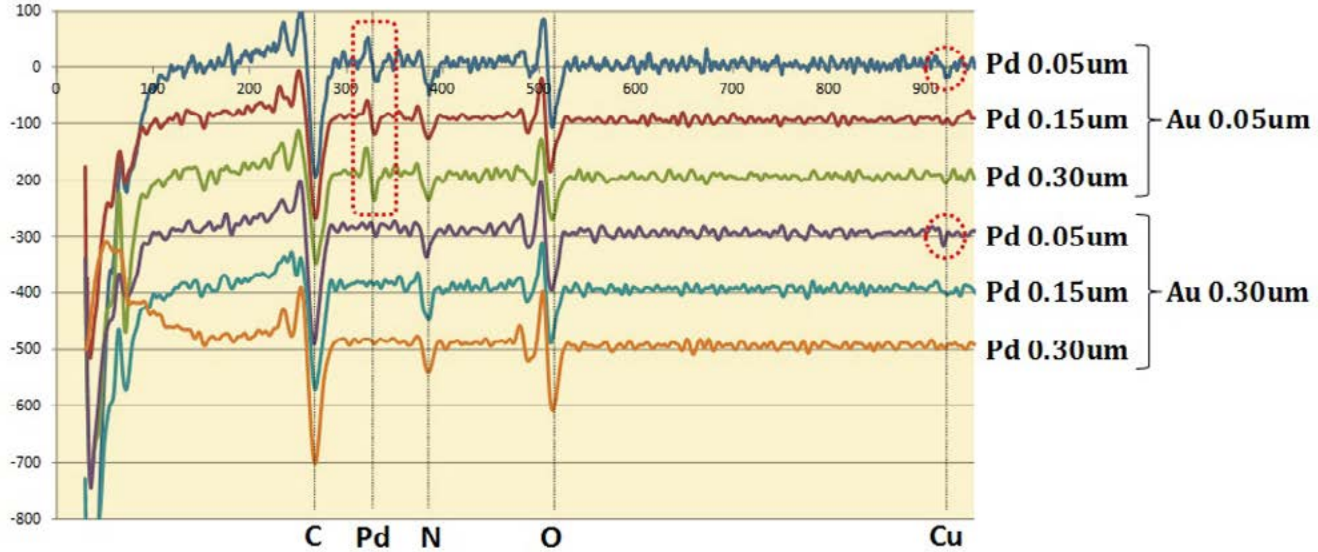


Figure 16: Wide scan results by AES; EPIG (Pd 0.05–0.30 μm, Au 0.05–0.30 μm) with heat treatment.

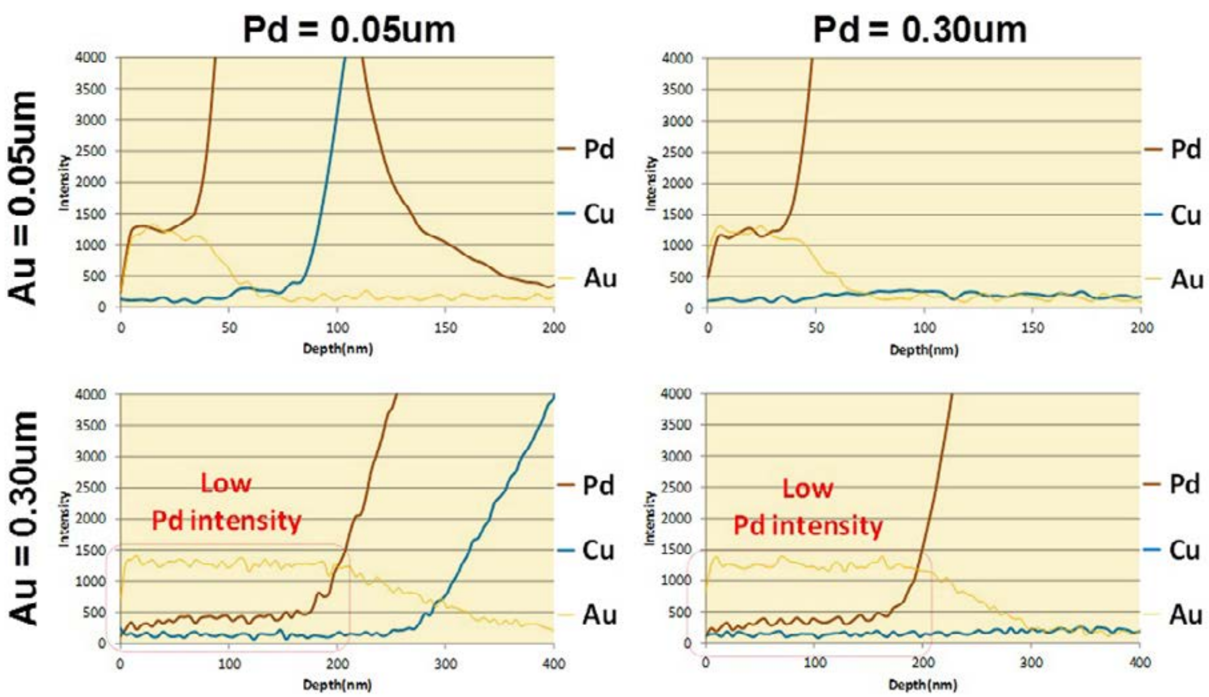


Figure 17: Depth profile results by AES; EPIG (Pd 0.05–0.30 μm, Au 0.05–0.30 μm) with heat treatment.

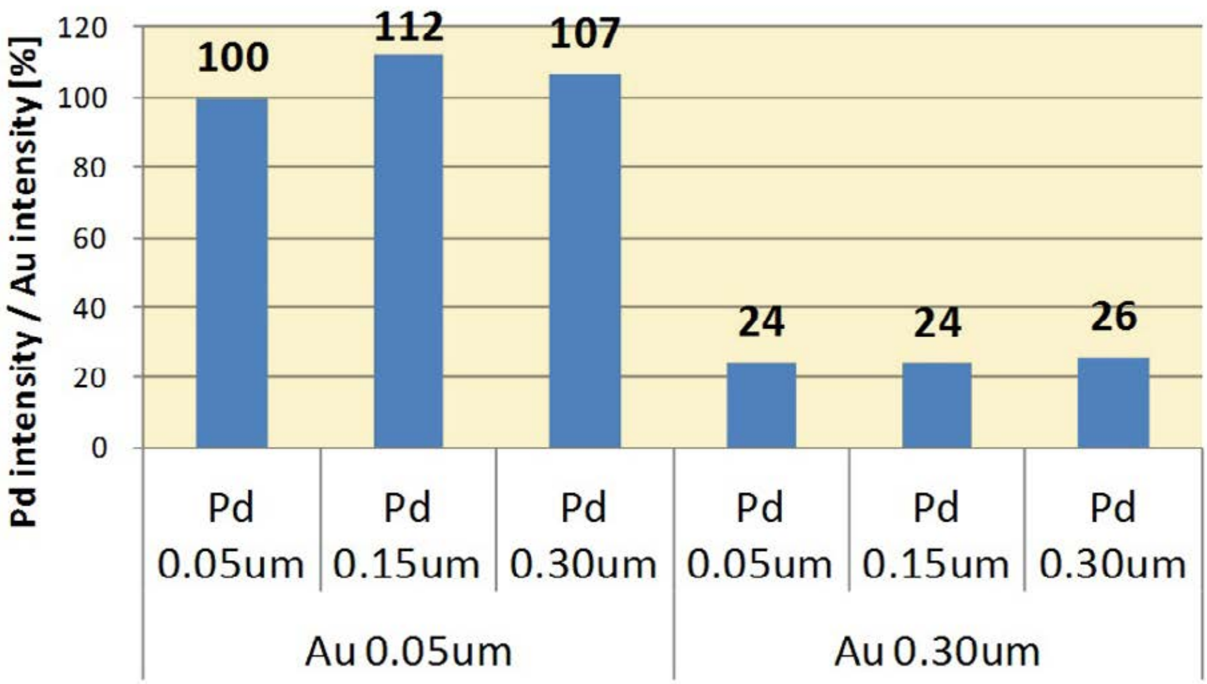


Figure 18: Ratio of Pd and Au intensity from depth profile by AES.

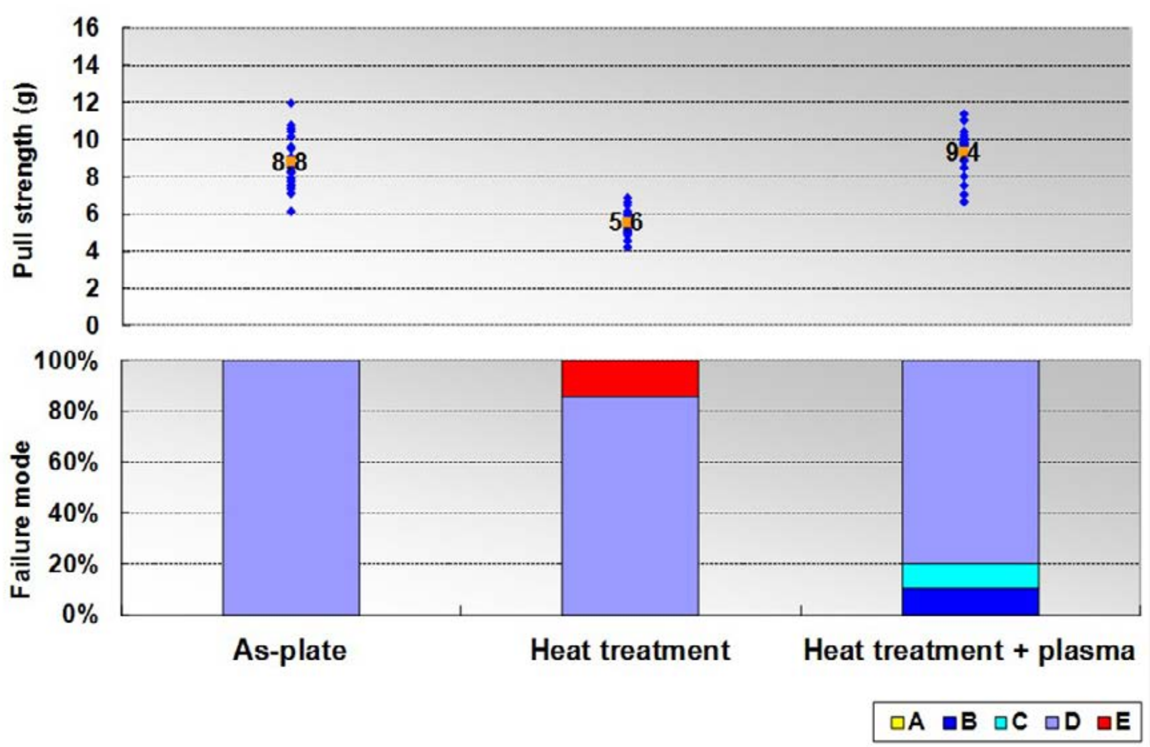


Figure 19: Wire pull test results; EPIG (Pd 0.1 µm, Au 0.1 µm) as plated, with heat treatment, with heat treatment and plasma treatment.

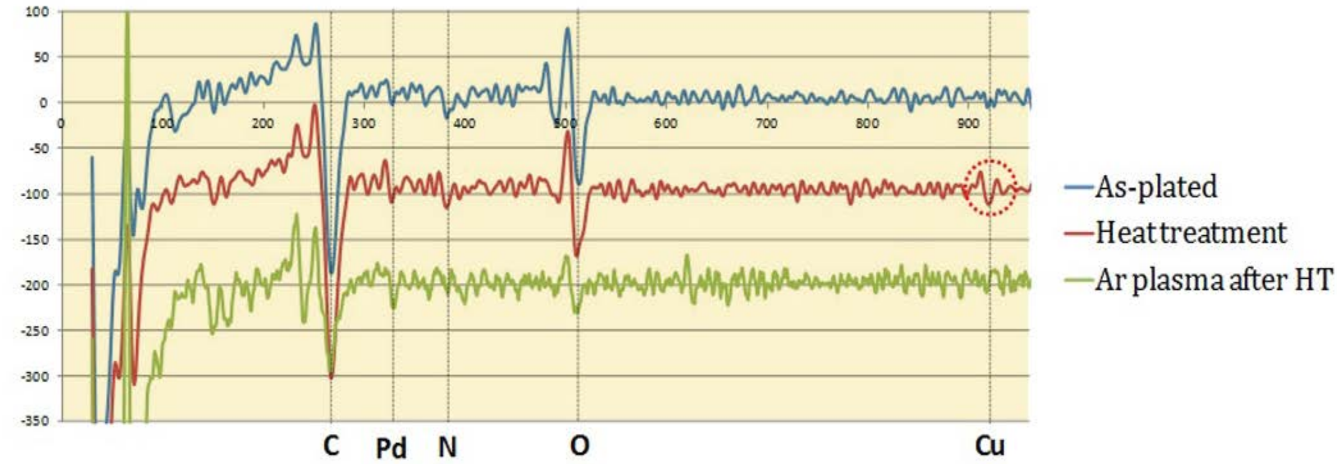


Figure 20: Wide scan results by AES; EPIG (Pd 0.1 μm, Au 0.1 μm) as plated, after heat treatment, after heat treatment and plasma treatment.

of 20 nm point from Au surface. It was considered that the diffusion of Pd was not dependent on Pd thickness, and was greatly dependent on Au thickness. The thicker Au layer will be important for keeping lower ratio of Pd in Au layer. This ratio of Pd in the Au layer was related to WBR after heat treatment.

From this study, when using the condition of heat treatment for 16 hours at 175°C used, Pd thickness at least 0.15 μm and Au thickness of 0.20 μm will be needed.

Plasma Treatment for Wire Bonding

The effect of plasma treatment for EPIG film after heat treatment was confirmed as shown in Figure 19 and Figure 20 with Ar being used for the plasma gas.

After plasma treatment, the strength of wire pull test and the broken mode became better, compared with that of the sample with heat treatment. It was confirmed by AES analysis that the peak of Cu was removed by the plasma treatment.

Conclusion

EPIG process had better pattern ability for narrow lines and spaces, compared with the ENEPIG process.

When using LF35 as the solder ball for EPIG deposits, thin and uniform IMC layers were formed. As a result, SJR became better.

When Au and Pd thickness was thinner, EPIG film had poorer WBR after heat treatment because Cu diffused onto the Au surface and the ratio of Pd in Au layer was higher. If using suitable Pd and Au thickness for EPIG, its WBR became better. In addition, it was suggested that WBR could be improved by plasma treatment to Au surface after heat exposure. **PCB**

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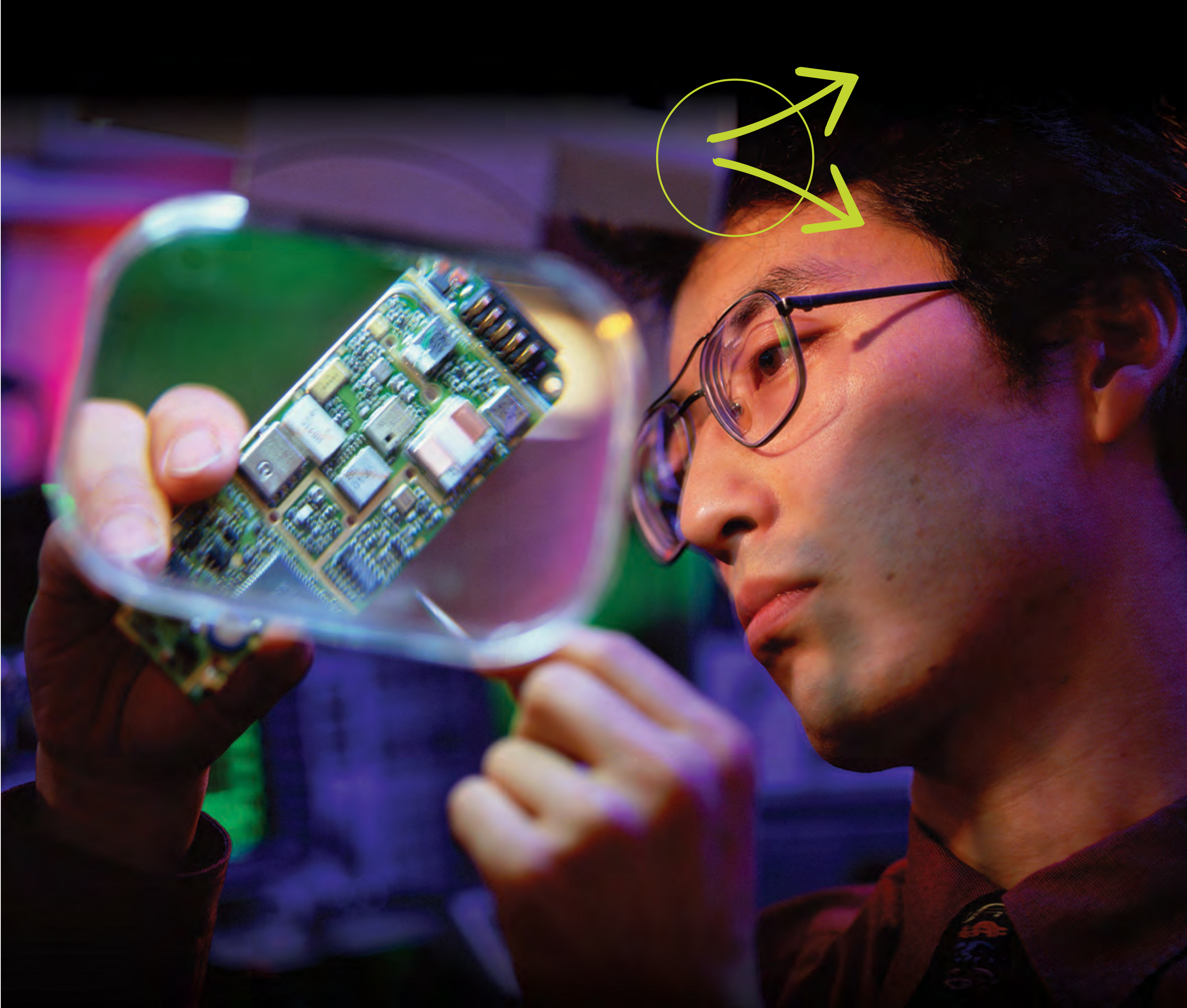

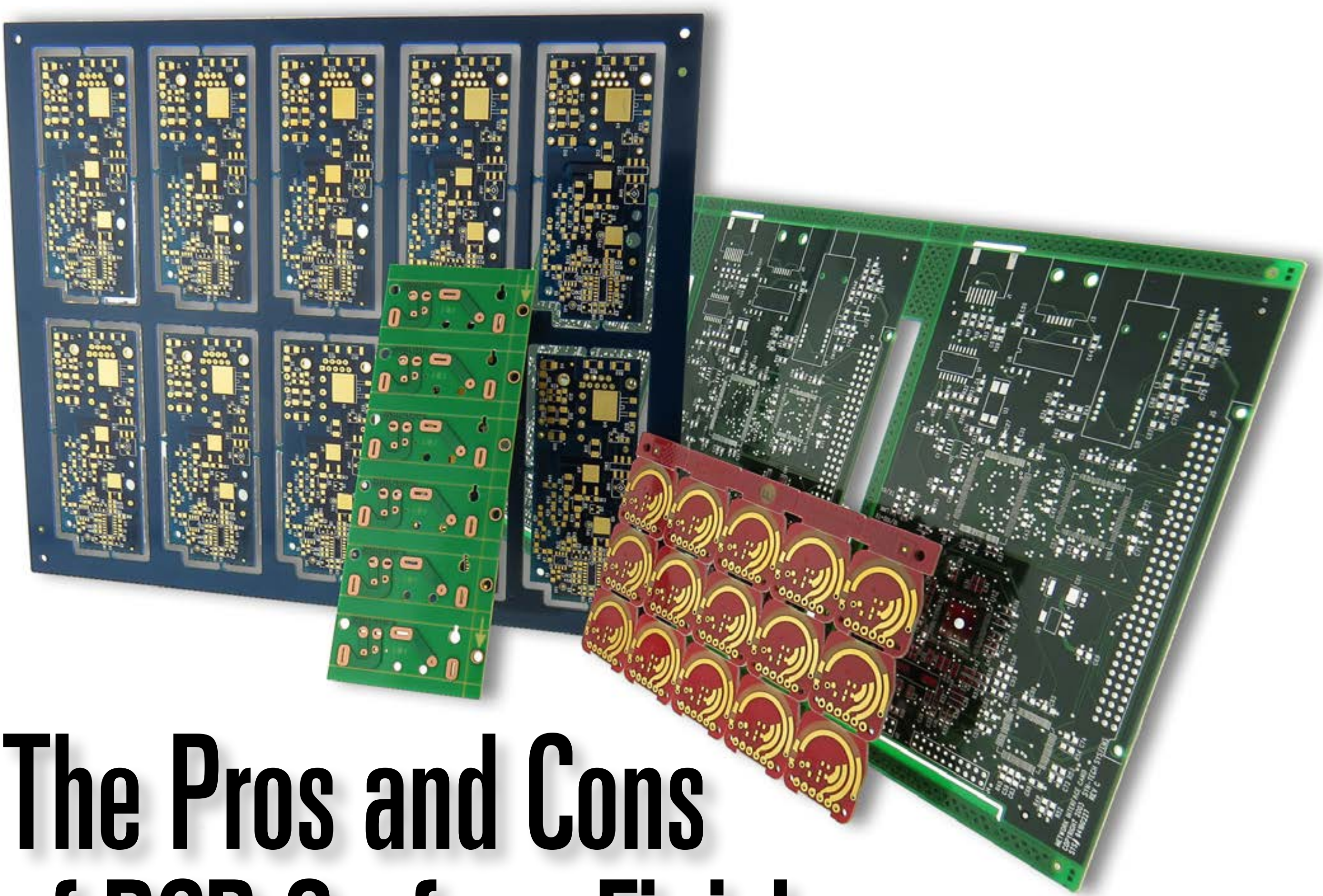

The Pros and Cons of PCB Surface Finishes

by Al Wright
EPEC ENGINEERED TECHNOLOGIES

Anyone involved in the PCB industry understands that PCBs have copper finishes on their surface and, if left unprotected, the copper will oxidize and deteriorate, making the circuit board unusable. The surface finish forms a critical interface between the component and the PCB. The finish has two essential functions: to protect the exposed copper circuitry and to provide a solderable surface when assembling (soldering) the components to the PCB.

Hot air solder leveling (HASL) was once the tried and true method of deliver consistent assembly results. However, ever-increasing circuit complexity and component density has stretched the capabilities of even horizontal solder levelling systems to their limits.

As component pitches became finer and the need for a thin coating became more critical, HASL represented a process limitation for PCB manufacturers. As an alternative to HASL, alternative coatings have been around for several years now, both electrolytic and immersion processes.

Here are some of the more common surface finishes used in PCB manufacturing, along with key advantages and disadvantages for each.

HASL/Lead-free HASL

HASL is the predominant surface finish used in the PCB industry. The process consists of immersing circuit boards in a molten pot of a tin/lead alloy and then removing the excess solder by using ‘air knives’ that blow hot air across the surface of the board.

One of the unintended benefits of the HASL process is that it exposes the PCB to temperatures up to 265°C, which will identify any potential delamination issues well before any expensive components are attached to the board.

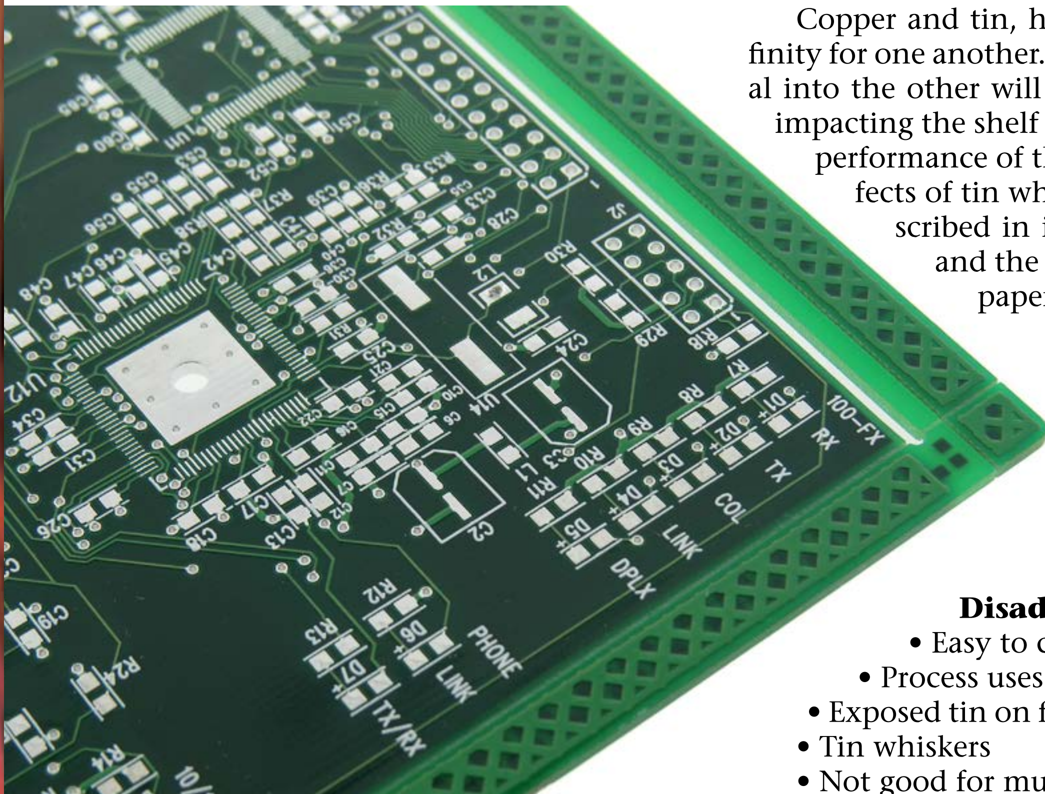

Figure 1: Printed circuit board with HASL/lead-free HASLs surface finish.

Advantages:
- Low cost
- Widely available
- Re-workable
- Excellent shelf life

Disadvantages:
- Uneven surfaces
- Not good for fine pitch
- Contains lead (HASL)
- Thermal shock
- Solder bridging
- Plugged or reduced PTHs (plated through holes)

Immersion Tin

According to IPC, immersion tin (ISn) is a metallic finish deposited by a chemical displacement reaction that is applied directly over the basis metal of the circuit board, that is, copper. The ISn protects the underlying copper from oxidation over its intended shelf life.

Copper and tin, however, have a strong affinity for one another. The diffusion of one metal into the other will occur inevitably, directly impacting the shelf life of the deposit and the performance of the finish. The negative effects of tin whiskers growth are well described in industry related literature and the focus of several published papers.

Advantages:
- Flat surface
- No Pb
- Re-workable
- Top choice for press fit pin insertion

Disadvantages:
- Easy to cause handling damage
- Process uses a carcinogen (thiourea)
- Exposed tin on final assembly can corrode
- Tin whiskers
- Not good for multiple reflow/assembly processes
- Difficult to measure thickness

OSP/Entek

Organic solderability preservative (OSP) or anti-tarnish preserves the copper surface from oxidation by applying a very thin protective

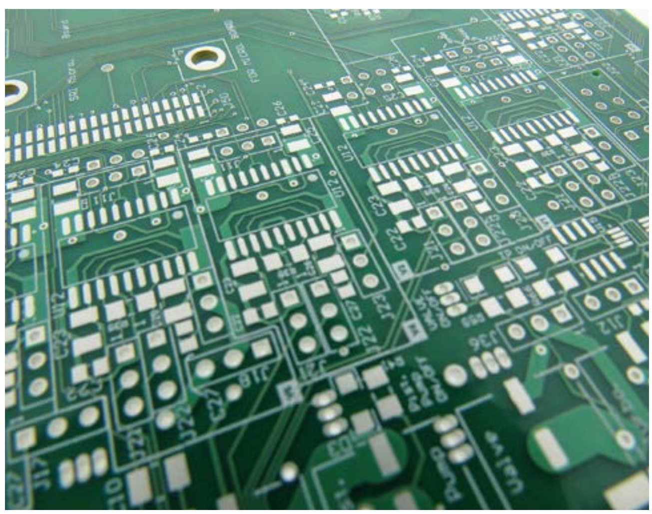

Figure 2: PCB with immersion tin surface finish.

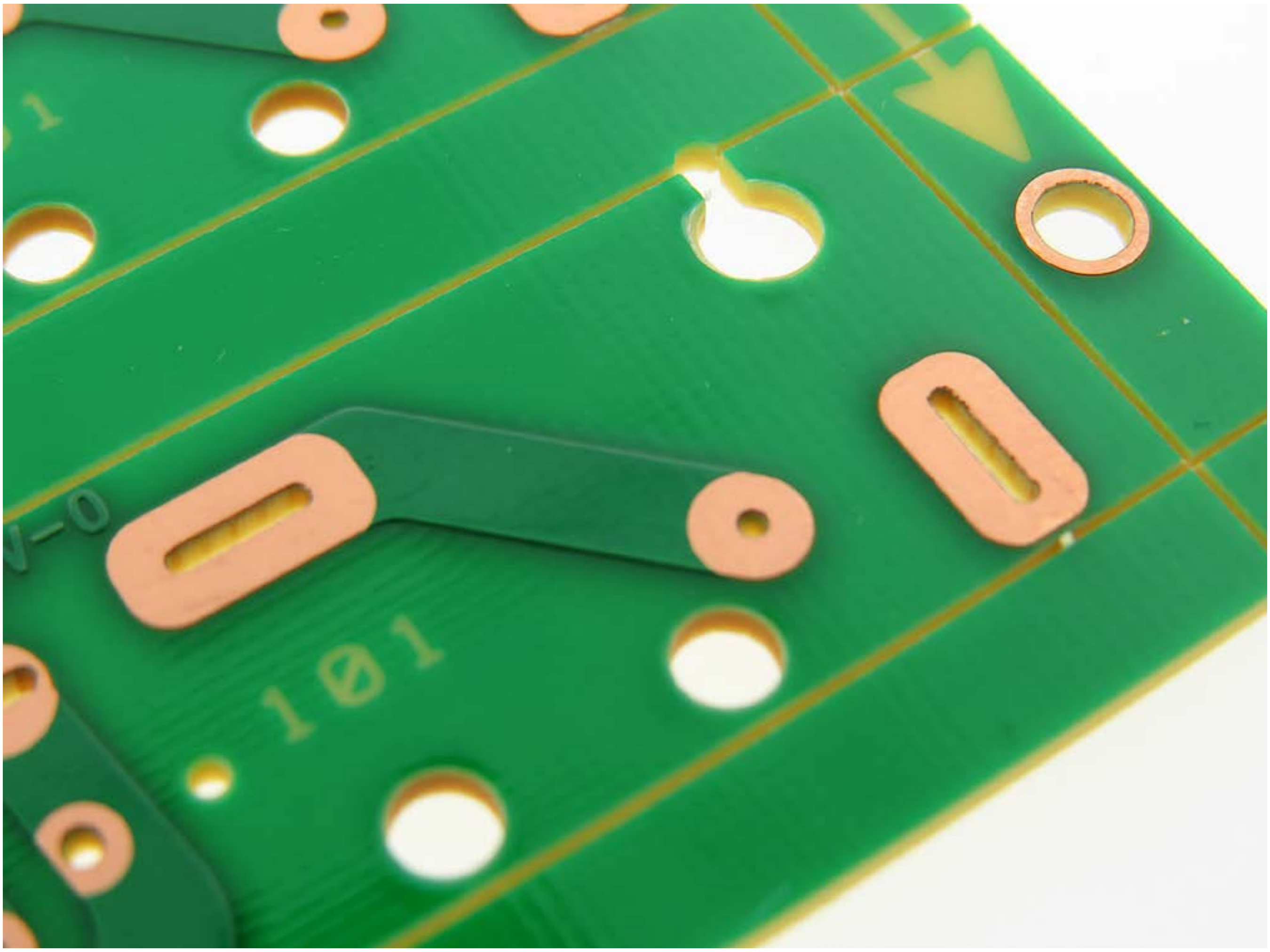

Figure 3: PCB with OSP/Entek surface finish.

layer of material over the exposed copper, usually using a conveyorized process.

It uses a water-based organic compound that selectively bonds to copper and provides an organo-metallic layer that protects the copper prior to soldering. It's also extremely green, environmentally, in comparison with the other common lead-free finishes, which suffer from either being more toxic or consuming substantially more energy.

Advantages:
- Flat surface
- No Pb
- Simple process
- Re-workable
- Cost effective

Disadvantages:
- No way to measure thickness
- Not good for PTH
- Short shelf life
- Can cause ICT Issues
- Exposed Cu on final assembly
- Handling sensitive

Electroless Nickel Immersion Gold (ENIG)

ENIG is a two-layer metallic coating of 2–8 µin Au over 120–240 µin Ni. The nickel is the barrier to the copper and is the surface to which the components are actually soldered to. The gold protects the nickel during storage and also provides the low contact resistance required for the thin gold deposits. ENIG is now arguably the most used finish in the PCB industry due the growth and implementation of the RoHs regulation.

Advantages:
- Flat surface
- No Pb
- Good for PTH
- Long shelf life

Disadvantages:
- Expensive
- Not re-workable
- Black pad/black nickel
- Damage from ET
- Signal loss (RF)
- Complicated process

Gold/Hard Gold

Hard electrolytic gold consists of a layer of gold plated over a barrier coat of nickel. Hard gold is extremely durable, and is most commonly applied to high-wear areas such as edge connector fingers and keypads.

Unlike ENIG, gold's thickness can vary by controlling the duration of the plating cycle, although the typical minimum values for fingers are 30 µin gold over 100 µin nickel for Class 1 and Class 2, and 50 µin gold over 100 µin nickel for Class 3.

Hard gold is not generally applied to solderable areas, because of its high cost and its relatively poor solderability. The maximum thickness that IPC considers to be solderable is 17.8 µin, so if this type of gold must be used on sur-

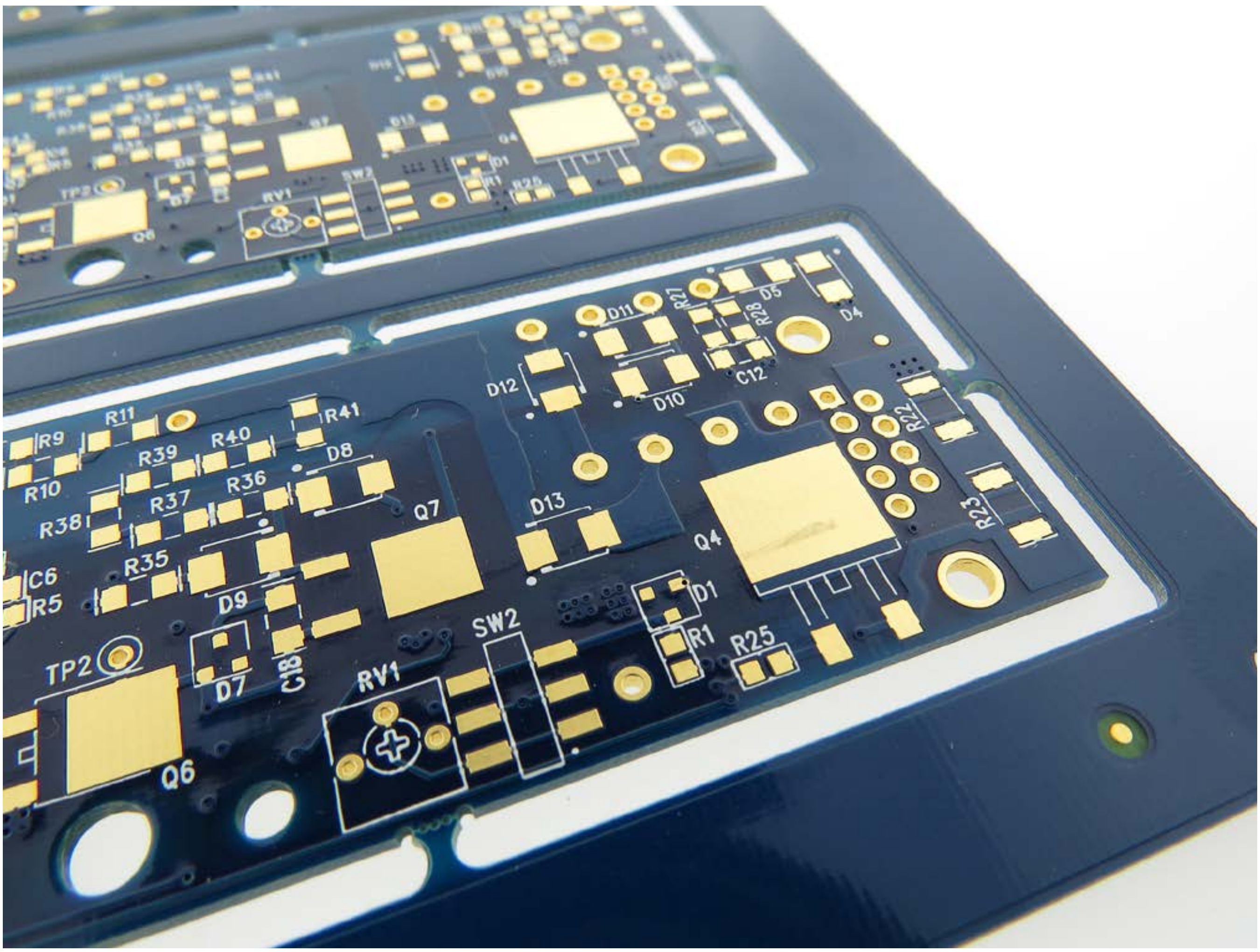

Figure 4: PCB with ENIG surface finish.


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Figure 5: PCB with gold/hard gold surface finish.

faces to be soldered, the recommended nominal thickness should be about 5–10 µin.

Advantages:
- Hard, durable surface
- No Pb
- Long shelf life

Disadvantages:
- Very expensive
- Extra Processing/labor intensive
- Use of resist/tape
- Plating/bus bars required
- Demarcation
- Difficulty with other surface finishes
- Etching undercut can lead to slivering/flaking
- Not solderable above 17 µin
- Finish does not fully encapsulate trace sidewalls, except in finger areas

Conclusion

It is important to select the appropriate surface finish for your project by considering the various options while factoring in performance requirements and material costs. For example, if you are looking for the lowest cost, then tin-lead HASL might seem like a good choice, but it is not suitable for RoHS-compliant products. If your product does require RoHS, you might consider lead-free HASL. But that is only if there are no fine pitch components, since LFHASL cannot be applied perfectly flat. If your design needs to be RoHS-compliant and uses fine-pitch components, then you'll need to select a flat, lead-free finish, such as immersion silver or ENIG. Bear in mind that doing so will necessitate the use of more costly high-temperature laminate.

Unsure of what you will need? Consult with a PCB fabricator prior to making a selection. This will ensure that the combination of the surface finish and material will result in a high-yielding, cost-effective design that will perform as expected. **PCB**

Al Wright is a PCB field applications engineer with Epec Engineered Technologies.

FEATURE

Determining Phosphorus Content in EN Plating Using XRF Spectroscopy

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FISCHER TECHNOLOGY
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HELMUT FISCHER GMBH

Abstract

Electroless plating processes are popular because of their performance, reliability and cost-effectiveness. The process combines unique deposit properties such as uniform plating build-up regardless of geometry, excellent corrosion resistance, superior hardness and wear, and the ability to plate on non-conducting materials. The most commonly used electroless plating process is electroless nickel (EN) plating using nickel phosphorus baths. The phosphorus content plays a fundamental role in all physical properties of the deposit. It is, therefore, critical to control the phosphorus content within a relatively tight range. X-ray fluorescence is an excellent method to not only measure plating thickness but also weight percent elemental composition of coatings. Previously, it was only possible to measure plated phosphorus content on steel substrates. New developments in XRF instrument hardware and software have extended the measurement application of electroless plating processes to nearly any substrate. The simultaneous measurement of thickness and composition is critical.

1. Introduction

Phosphorus, the concentration of which significantly influences the mechanical and magnetic properties of the coating, is incorporated during electroless or chemical nickel deposition[1]. For this reason, measurement of the phosphorus content has been an important issue ever since electroless nickel deposition methods were introduced. As an alternative to the established wet-chemical methods, during which the coating is dissolved and therefore destroyed, non-destructive and simpler methods are desired. XRF provides such a non-destructive test method, where utilisation of the characteristic emissions of P-K radiation can

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imagine no set-ups

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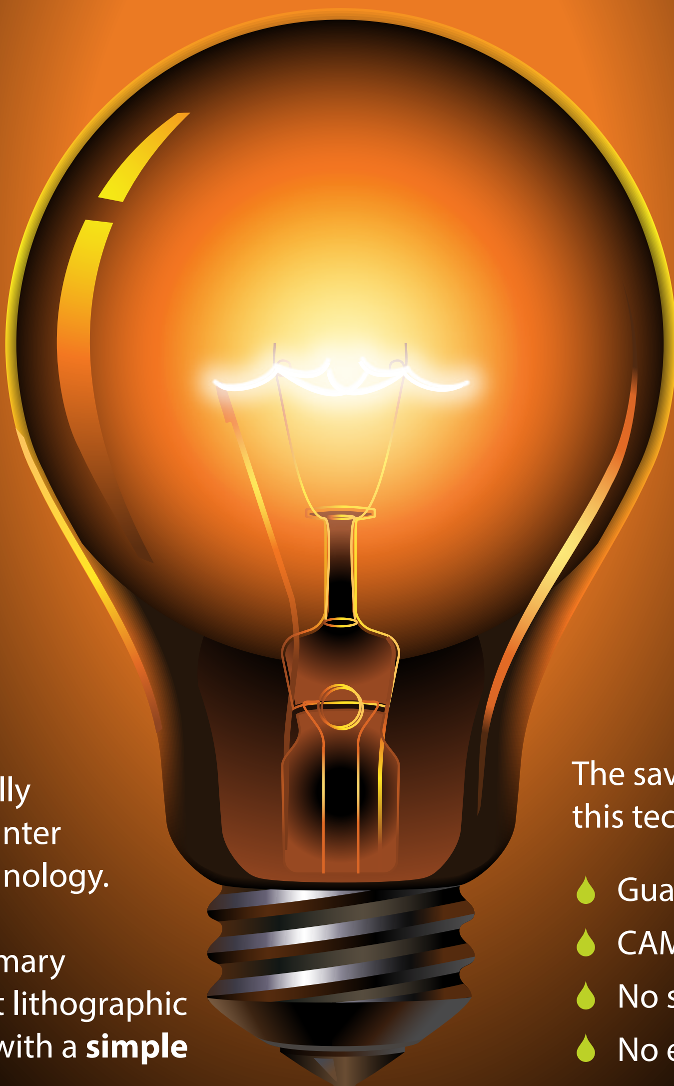

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provide direct measurement of the phosphorus content. Energy-dispersive X-ray spectrometry (EDX) utilizing electrons for excitation in electron probe microanalysis (EPMA) or charged particles in particle induced X-ray emission (PIXE) have been analytical techniques used for determining phosphorous content for a long time. While the first method is integrated into many electron microscopes, the latter requires an accelerator. High vacuum is required in either case. In XRF, an incident X-ray beam is used as the excitation source. This is typically an X-ray tube.

For all three described excitation methods, the resulting fluorescent signal is interpreted in the energy dispersive X-ray spectrometer. XRF is well established in process control instrumentation, especially in the electroplating industry and has been used for decades to determine both coating thicknesses and coating compositions[2]. However, it is impossible to determine the thickness of a nickel/phosphorus coating using X-ray fluorescence without knowing the phosphorus content. The phosphorus content in the nickel changes the coating density and attenuates the other fluoresced components used in the measurement process. The phosphorus concentration of a nickel/phosphorus alloy coating has been obtained indirectly, by measuring the attenuation of base material fluorescence as described in section 2.2. This method, without directly measuring the P-K signal, was described in 1989[3] and is integrated in some instrument manufacturers' application software. Reliable direct measurement of the P-K radiation has been limited in conventional, air path XRF instruments by detector technology (i.e., proportional counter tubes or Peltier-cooled Si-PIN diodes). The low-energy P-K radiation can either not be detected or insufficiently detected. Nonetheless, this widely used technique has great advantages; it requires no vacuum and operation of the instruments is simple enough that it can be used on the plating floor. Now with the recently available silicon drift detectors (SDDs) direct measurement of P-K radiation in air is possible and, therefore, extends the application to base materials other than Fe, such as Al or plastics.

The following discusses this in greater detail.

2. Direct and Indirect Determination of the Phosphorus Content

2.1The Coating Model

In the coating model depicted below (Figure 1), the nickel/phosphorus coating is viewed as a plane parallel alloy coating that contains only the elements nickel and phosphorus with a homogeneous element distribution. Typically, organic and/or metallic stabilisers (i.e., lead) in trace concentration ranges can be neglected. If lead-free stabilisers are present in concentrations that affect the XRF analysis, they can be taken into account as an additional alloy element or elements.

The radiation components relevant for XRF are Ni-K (7.5 keV and 8.3 keV) and P-K (2.0 keV), as well as the fluoresced components of the substrate material, which in Figure 1 is iron (6.4 keV and 7.1 keV).

2.2 Indirect Phosphorus Measurement

The indirect determination of the phosphorus content[3] uses only the easily measurable radiation components of nickel and the substrate material iron. This approached is used with proportional counter tube based instruments, because a proportional counter tube is not able to detect the P-K radiation. Figure 2 shows related model calculations for the conditions of a Fischerscope X-ray XULM proportional coun-

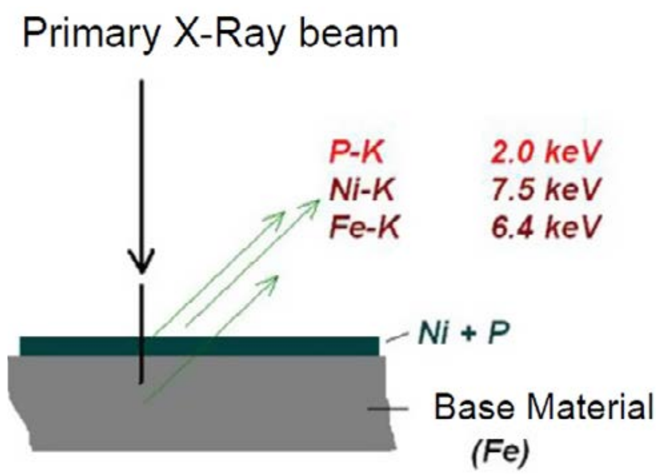


Figure 1: Coating model and schematic of the fluorescence excitation.

ter system. Displayed are the modeled spectra for a 5 µm-thick nickel/phosphorus coating on iron, with the phosphorus content varying between 0% and 15%.

One notices a clear dependence of the Ni and Fe intensity with respect to the phosphorus content. The physical reason is the absorption effect of the element phosphorus on both the Fe-K and the Ni-K radiation. So, there is a well-defined correlation between the thickness of the nickel/phosphorus coating and its phosphorus content as the unknown measurement variables and the intensities of Fe-K and Ni-K radiation that can be measured with a proportional counter tube. For a constant thickness, more phosphorus reduces the Ni-K intensity relative to the Fe-K intensity, because the absorption by phosphorus is less for iron than nickel. The evaluation software WinFTM [2] processes this information and computes the thickness and the composition of the coating from the measured spectrum. Table 1 shows the results obtained from the measurement of a flat NiP/Fe reference sample. The measuring application was not calibrated (standards-free analysis). The small deviation from the nominal value indicates that the model underlying the evaluation is quite good. Even more important is the good precision of 0.25% for the phosphorus concentration. However, it is apparent that the total measurement uncertainty increases due to systematic uncertainty (Section 3).

An error due to possible distance variations must be considered as part of the random measurement uncertainty. A shift in the measurement distance results in a change in intensity of all spectral components and in particular, in erroneous %P readings

Figure 3 illustrates this based on the specimen from Table 1.

In general the uncertainty of the measuring distance setting z is better than 50 µm, such that, the resulting uncertainty in determining the concentration is about 0.2% phosphorus. If one further considers that a positioning uncertainty also occurs during calibration, then this error source must be estimated at about 0.3% phosphorus. This is the same magnitude as the precision itself. Other sources of error (influence of curvature and tilt of the specimen surface) during the indirect measurement of NiP/Fe can also contribute to the total error.

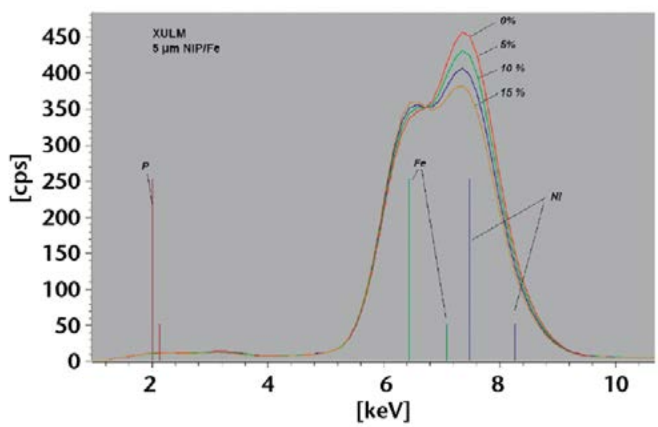


Figure 2: Computed spectra for a 5 µm-thick nickel/phosphorus coating on iron, applicable for the measurement conditions of a Fischerscope® X-ray XULM, 50 kV, Ni-filter. The detector is an Xe-filled proportional counter tube. It is not possible to evaluate the P-K peak at 2 keV with this type of detector.

Fischerscope® X-ray XDLM-C4
Application: 216 / NiP/Fe

Individual results		
n = 1	P Ni1 = 13.0 µm	P 1 = 9.45%
n = 2	P Ni1 = 12.9 µm	P 1 = 9.23%
n = 3	P Ni1 = 13.1 µm	P 1 = 9.63%
...		
n = 10	P Ni1 = 13.1 µm	P 1 = 9.52%
Mean value	12.96 µm	9.395%P
Standard deviation	0.099 µm	0.25%P
Number of measurements	10	10
Lowest reading	12.8 µm	8.98%P
Highest reading	13.1 µm	9.83%P
Measuring time	30 s	

Table 1: Measurement documentation for the standards-free thickness and composition determination of a NiP/Fe reference sample (14.3 µm, 9.3% P); Measurement under repeatability conditions.

One aspect of the distance dependence often surprises the user: Newer model instruments with high-resolution semiconductor detectors are not at all suited for this approach, because the distances between sample and detector are significantly smaller. For this reason, distance uncertainties of the same magnitude, i.e., <50 µm, are significantly more serious (by a factor of 2–3!) than with proportional counter tube instruments. This must be taken into account when evaluating spectra with a direct phosphorus analysis (Section 2.3).

2.3 Direct Phosphorus Measurement (analysis of P-K- Peak)

SDDs can achieve today what was impossible with even Si-PIN detectors of the last decade. The P-K radiation component can be detected reliably. Figure 4 graphically illustrates the measurement effect. Samples with different phosphorus contents show P-K peaks of different magnitudes. Their intensities are (nearly) proportional to the phosphorus content.

The energy of the characteristic P-K radiation is only 2 keV. Due to the very critical dependence of the absorption coefficient on the photon energy, the information depth is just under 1 µm (Figure 5).

As shown in Figure 6, the spectral signal of the phosphorus is not very large. For commonly used excitation conditions (W- Anode, 50 kV, 10 µm Ni-filter) and a typical sample of about 10% P, the P-K peak is 2000 times smaller than that of Ni-K. This combined with a rather poor signal/background ratio of only two provides unfavourable conditions for routine analyses. The signal/background ratio, which is so important for the measurement sensitivity of phosphorus, can be increased by a factor of 4 through "soft" excitation, as demonstrated by the yellow 10 kV-spectrum shown in Figure 6.

Unfortunately, lowering the excitation voltage of the X-ray tube, which is favourable for the detection of phosphorus, is not effective for thickness measurement. The solution is to combine both types of excitation in one mea-

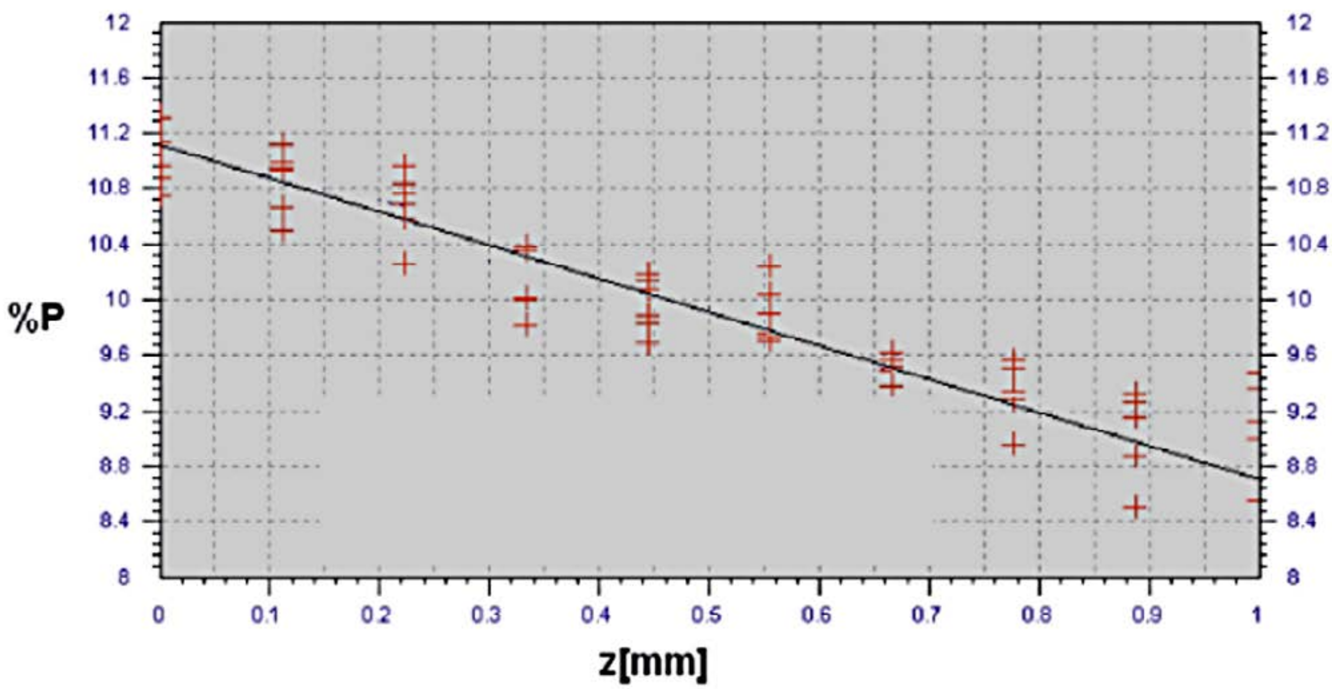


Figure 3: Measured distance dependence of the %P measurement using a Fischerscope X-Ray XDLM-C4 for the sample from Table 1; the correct measuring distance is z = 0.5. The measurements are repeated several times, and the scatter provides a measure for the random (statistical) measurement error.

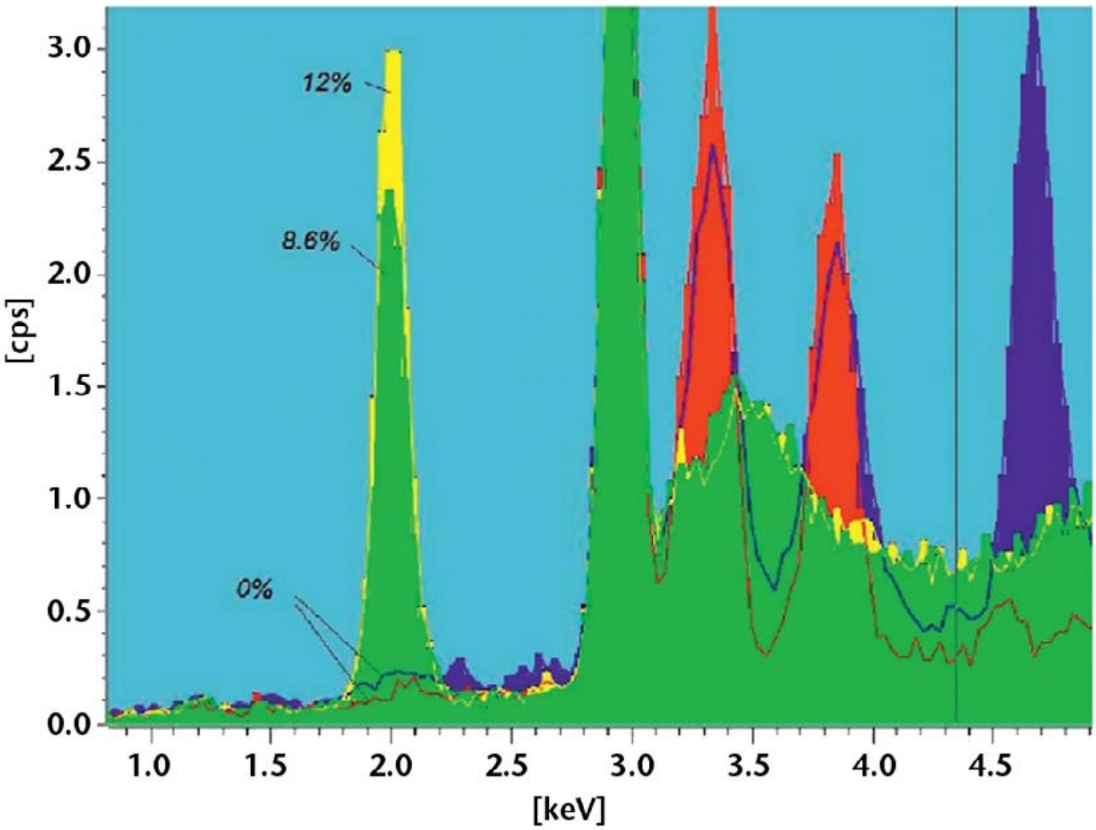


Figure 4: Fluorescence spectra of nickel/phosphorus coatings with different phosphorus content: the intensity of the P-K peak directly represents the phosphorus concentration.

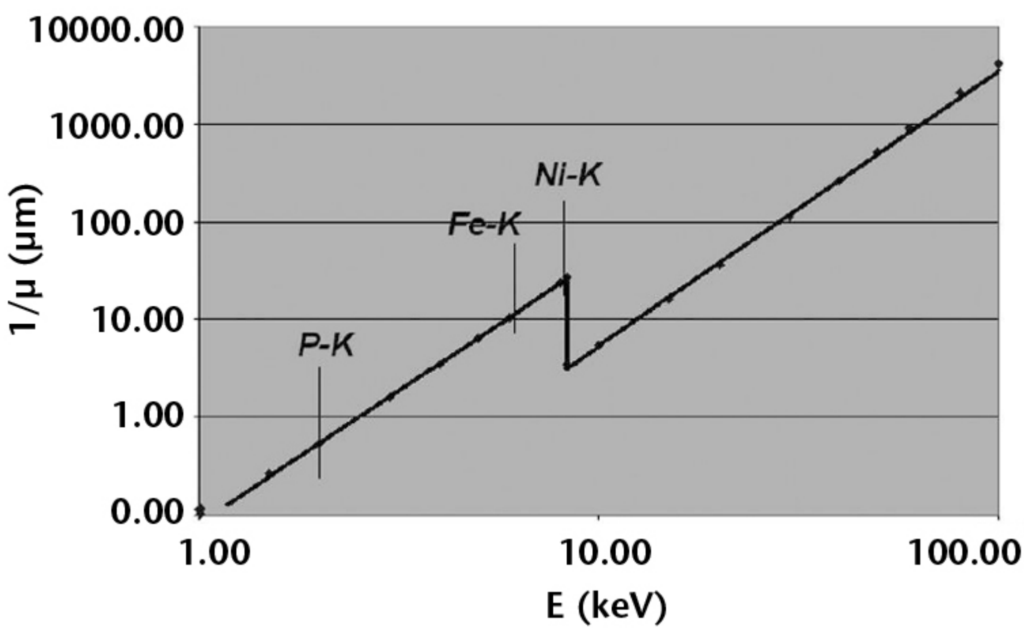


Figure 5: Information depth dependence (reciprocal linear attenuation coefficient) for the element nickel.

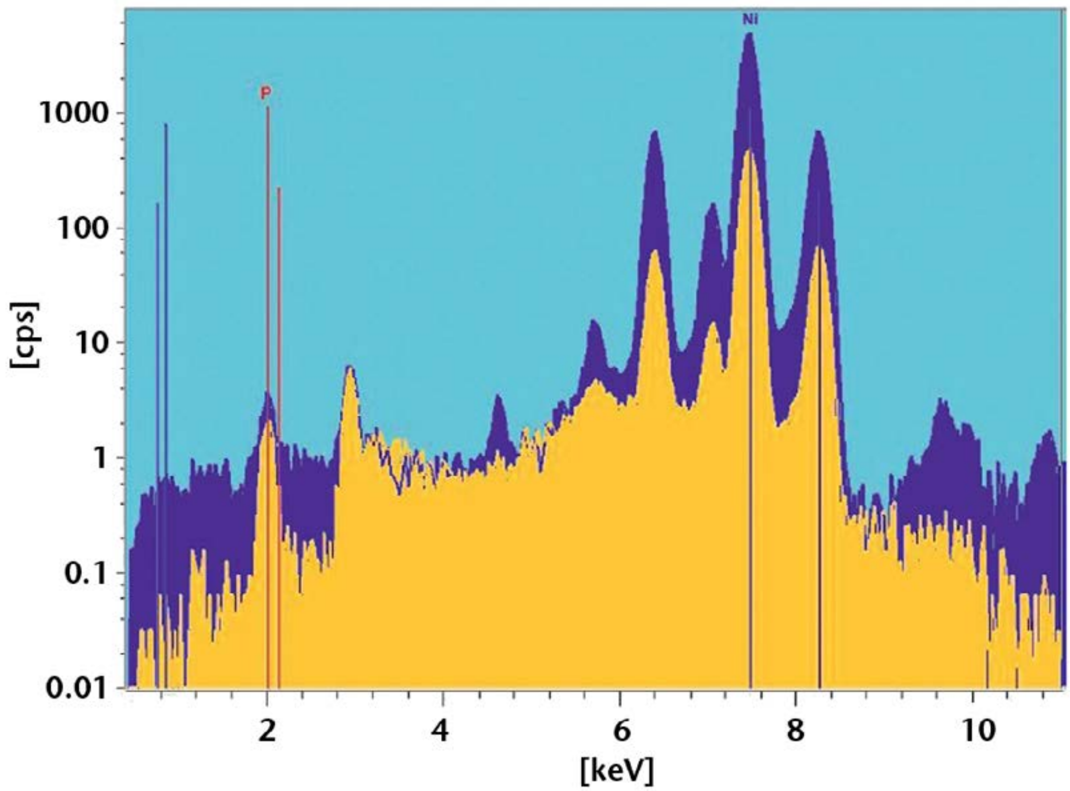


Figure 6: Fluorescence spectra (log intensity scale) of a NiP/Fe sample (14.3 µm, 9.3 % P) for different excitation conditions: 50 kV, 10 µm Ni-Filter (blue) and 10 kV non-filtered (yellow). Fischerscope X-ray XDV-SDD, aperture Ø 1 mm, anode current in both cases = 1 mA.

surement (multiple- excitation). In the process, multiple spectra are obtained for one measurement.

For EN measurement, two excitations are sufficient: the first 50 kV "hard" excitation is used for the coating thickness measurement and the "soft" 10 kV excitation for the phosphorus content.

3. Measurement Uncertainty and Reference Samples

Although standards-free measurements do deliver quite reasonable results with properly set-up instruments (Table 1), a calibration with reference samples and corresponding adjustment is essential for accurate routine measurement. For this reason, calibration standard sets consisting of several nickel/phosphorus samples with various phosphorus concentrations have been developed for the substrate materials iron, aluminium, copper and for printed circuit boards. Traceability is established using ICP-OES analyses of three independent laboratories. Their good correlation to standards- free XRF values is presented in Figure 7. Deviations from the regression line have various causes. As a whole, they represent the systematic measurement uncertainty, which can be estimated at about 0.3% phosphorus. Thus, the total measurement uncertainty can be assessed to be about 0.5% phosphorus.

4. Measurement Examples

4.1 Nickel/Phosphorus on Aluminium—Thickness and Composition

Table 2 shows the measurement results from an application for determining the thickness and composition of a nickel/phosphorus coating on any desired substrate material.

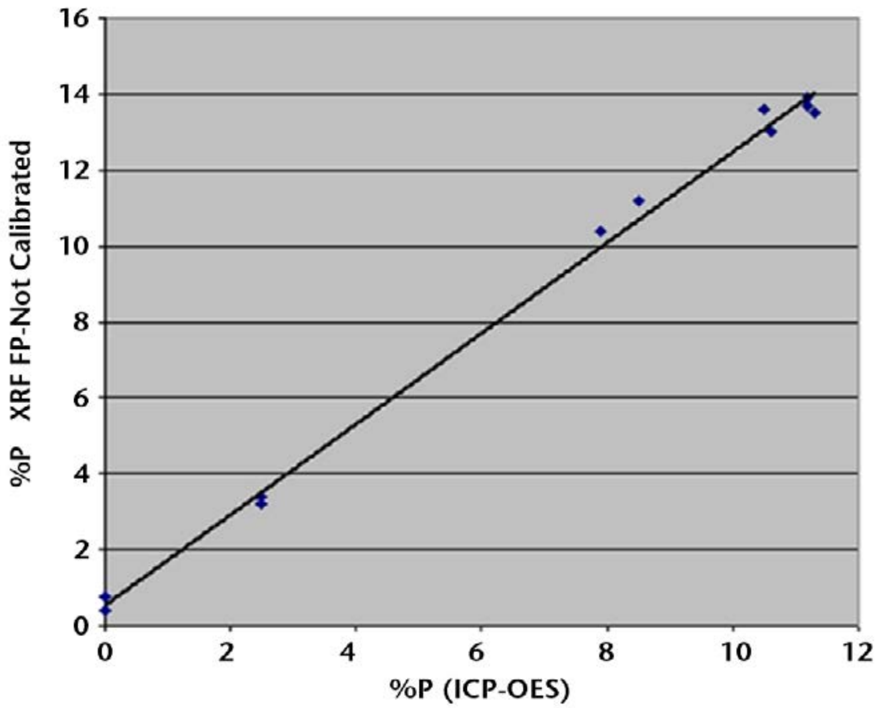


Figure 7: Comparison of the destructive chemical analysis (ICP-OES) with previously determined XRF results. XRF measurements were performed standards-free according to the method described in[2].

4.3 Nickel-Phosphorus on a Printed Circuit Board

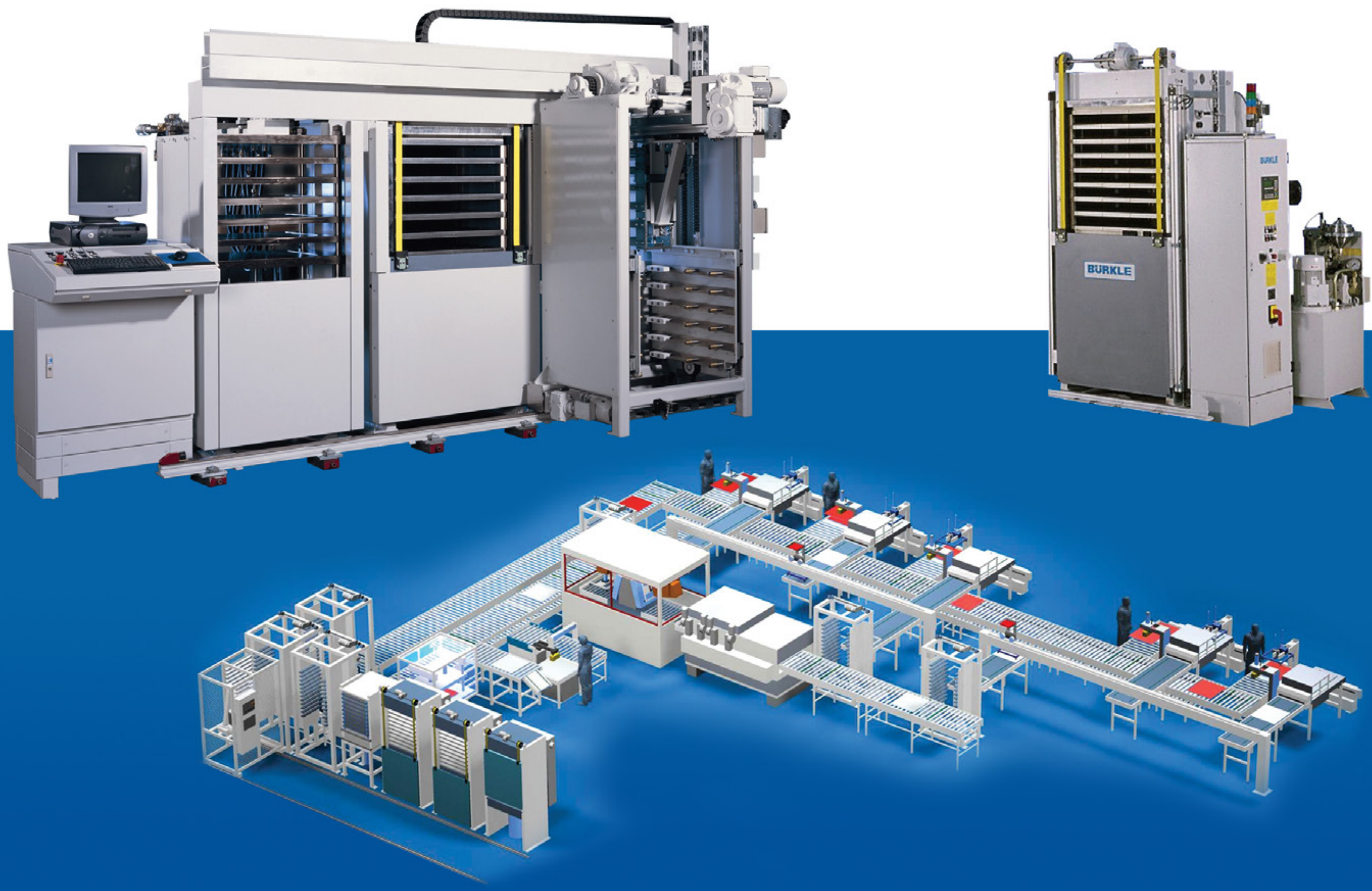
Printed circuit boards are an important application for nickel/phosphorus coatings, on top of which, additional gold and/or palladium coatings are applied. The phosphorus content cannot be determined through these surface layers—the low energy P-K emission is absorbed. So, Au and Pd must be stripped prior to analysis or the uncoated nickel/phosphorus coating must be measured. The measuring application must be designed such that the copper undercoat does not influence the spectra evaluation. Coatings of a few tenths of a micron can then be measured. The measurement uncertainty is comparable to the example in Table 2.

Fischerscope X-ray XDV-SDD		
Application: 290 / NiP/Al multiple times		
Single readings		
n= 1	P Ni1= 8.652 µm	P = 11.59 %
n= 2	P Ni1= 8.701 µm	P = 11.39 %
n= 3	P Ni1= 8.730 µm	P = 11.92 %
...		
n= 10	P Ni1= 8.733 µm	P = 11.79 %
Mean value	8.687 µm	11.57 %
Standard deviation	0.045 µm	0.232 %

Table 2: NiP/Al (hard disk): Excitation 50 kV with Al 0.5 mm filter and 10 kV non-filtered. Aperture Ø 3 mm, measuring time 20 s per excitation, 10 individual measurements at the same location (repeatability measurements).

Fischerscope X-ray XDV-SDD	
Application: 325 / NiP	
Individual results	
n = 1	P = 11.43 %
n = 2	P = 11.36 %
n = 3	P = 11.68 %
...	
n = 10	P = 11.54 %
Mean value	11.72 % P
Standard deviation	0.219 % P
Measuring time	30 sec

Table 3: Measurement of the phosphorus concentration; XDV-SDD, 10 kV non-filtered, aperture Ø 3 mm, measuring time 30 s, 10 individual measurements at the same location (repeatability measurements).



4.4 Phosphorus Only Analysis

The phosphorus content can be determined independent of the coating thickness if the thickness is greater than 3 µm (Table 3). Only the soft 10 kV excitation is used and the measuring time is half of that of the complete analysis.

5. Summary

New developments in XRF hardware and software technology have made it possible to simultaneously measure the percent of phosphorous and NiP coating thickness in air. Being able to measure the phosphorous content directly now allows determination of the percent of phosphorous in electroless Ni-plantings on substrates in addition to iron, such as, Al or even non metallic substrates. Instruments with SDDs can measure the P-K radiation quite well using soft primary excitation (10 kV, non-filtered). Coating thickness is determined using harder excitation (30 keV or 50 kV).

The information depth for phosphorus is relatively low (<1 µm) due to the low energy of P-K fluorescence.

Conventional indirect determination of phosphorus can still be regarded as a relatively robust method with proportional counter tube instruments – the only option with these instruments.

The use of appropriate reference standards is highly recommended. **PCB**

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VIDEO INTERVIEW

ENIG Leader Uyemura Expands into New Markets

by Real Time with...productronica 2013

Uyemura Director of Operations Donald Walsh discusses Uyemura's unique copper and finishing processes, as well as the recent expansion from a dedicated focus on bare boards to providing conformal coatings to the assembly sector as well.

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PCB007 Supplier/New Product News Highlights

Camtek Moves Forward with GreenJet Development

Ha'emek, Israel-based Camtek Ltd. recently reconfirmed to the media and its investors that it was in advanced stages of developing GreenJet, its digital 3D printing system for the deposition of soldermask designated for the PCB industry.

Atotech Unveils New Through-Hole Fill System

"This new equipment can completely fill through-holes, such as those laser drilled in panels up to 200 µm thick with a surface diameter of 100 µm. It is the only horizontal production system worldwide which can provide a consistent inclusion-free copper filling."

Enthone Develops Supplier Quality Engineering Audit

Enthone has introduced a comprehensive Supplier Quality Engineering (SQE) audit to enable the immediate identification of PCBs coated with the company's patented ENTEK organic solderability preservatives. The audit includes OSP verification, process line optimization, and consultation on other PCB final finish options based on application requirements.

DuPont Expands Printed Electronics Product Line

DuPont Microcircuit Materials (DuPont) is expanding its suite of low silver, conductive ink materials specifically tailored for membrane touch switch (MTS), radio-frequency identification (RFID), and wearable electronic applications.

Atotech Innovates the Surface Finish Process

To comply with new technical requirements, as well as cost and environmental regulations, the PCB industry is constantly searching for alternative manufacturing solutions. Atotech's solution is a new direct palladium surface finish process (PallaBond) with an optional gold layer. The process allows the direct deposition of palladium on copper, without using any nickel.

Technica to Assume NGS Product Line

"The NGS product line is a great complement to the other products Technica distributes to the printed circuit board manufacturing industry, chemical milling, and other related markets," said Jerry Shirley, president of NGS, Inc.

LPKF Raises 2013 Guidance

LPKF remains on track for success, even though revenue growth has slowed somewhat in the year's third quarter, as expected. After rising by almost 40% in the first six months of the year, the nine-month revenue posted by the laser equipment manufacturer is up 21% over the prior-year period.

PCB Solutions Offers Expanded Stocking Program

The company is now offering a complete stocking program that enables customers to take advantage of volume pricing, but assists them with cash flow and inventory relief. Customers are allowed to stock their inventory at their own facility and pull releases based on purchase order requirements.

National Technology Announces Equipment Investments

President Bob Keisler says, "Our customers continue to drive us technologically, with more demanding and complex needs and requirements. The technological edge is not limited to product processes alone; our environmental policy assures that both of our facilities surpass all compliance regulations in effect, not only today, but in the future as well."

Option Technologies Continues Growth in North America

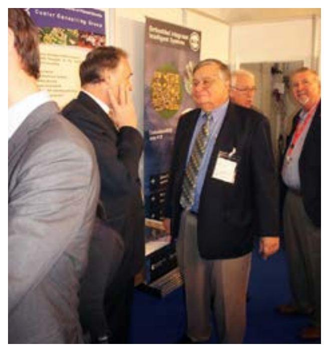
Managing Director Steve Law explains, "Option has been supplying this market since 2004 and has established a very loyal customer base over the years. We have now opened a sales office in the U.S. to help manage the increasing demand for drilled mass-lam, and have appointed Ray Breton to head the sales operation."

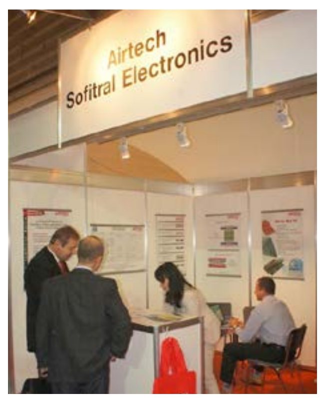
productronica 2013

by Pete Starkey
I-CONNECT007 TECHNICAL EDITOR

Four November days in Munich—the 20th productronica. More than just an exhibition: an international trade fair for innovative electronics manufacturing. In all, 1,220 companies from 39 countries exhibited their equipment, materials, processes and services to 38,000 visitors from 83 countries.

I haven't missed productronica many times over the last 30 years; I've always seen it as the one event that represents the whole electronics supply chain and offers a glimpse into the future of the industry. It hit an all-time low in 2009, and I recall John Ling's wistful analogy of visiting a much-loved but ailing elderly relative in hospital, and fearing the worst. Two years later, the elderly relative was showing signs of improvement and this year appeared to be recovering to a state





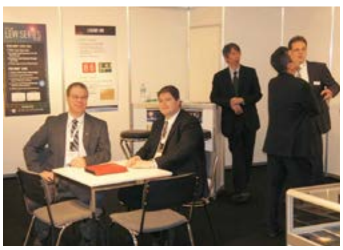
productronica 2013

of robust health! The organisers reported a sharp increase in the number of visitors from abroad—especially from non-EU countries, and particularly from the Russian Federation, China and Turkey.

There was a positive energy about the place—plenty of traffic, plenty of activity and real business being done by the exhibitors. No tire-kickers this year, people were not dreaming of what they might have liked to buy if they could have afforded to. They had come with real money to spend, and they were prepared to spend it, albeit selectively in carefully-considered transactions.

Although it is subject to increasing competition from far-Eastern events, productronica is still rated the number one electronics industry gathering in the world. And it didn't snow this time! Interesting to see what 2015 brings…

But for now, enjoy these images from the show! For full *Real Time with...* coverage, click here. **PCB**



Mil/Aero007 News Highlights

Ducommun Gains Major Parker Aerospace Airbus Contract

The company has received a multiyear contract from Parker Aerospace, a unit of Parker Hannifin Corporation, to produce complex PCBs assemblies for use in the fuel management system of the Airbus A350 family of commercial aircraft. The award has a potential value in excess of $20 million over the contract period.

Sparton, USSI JV Nets $2.8M in Subcontracts

Sparton Corporation and USSI, a subsidiary of Ultra Electronics Holdings plc, announce the award of subcontracts valued at $2.8 million from their ERAPSCO/SonobuoyTech Systems joint venture.

Axis Leads 2014 UK Aerospace Youth Rocketry Challenge

Axis Electronics apprentices joined more than 25 MPs who teamed up with aerospace apprentices from all over the UK to take part in a rocket launching competition. The aim was to achieve the greatest vertical distance.

Blackfox, Lockheed Martin Celebrate 'Hire a Veteran Month'

Last month, Denver, Colorado's 9news featured a segment with Andrew Stone of Lockheed Martin discussing his company's plan to hire nearly 180 veterans for high-tech positions in assembly during Hire a Veteran Month.

ESCATEC is Founding Member of Swiss Photonics Group

"Being a founding member of this SWISSMEN professional group for the Photonics industry, puts ESCATEC in a very good position to support this growing industry in Switzerland with ESCATEC's outstanding knowledge and experience in research, design, and development," said Dr. Thomas Dekorsy, general manager.

IMET is Philadelphia's Manufacturer of the Year

IMET Corporation, a contract manufacturer providing electronics engineering services and PCB assembly, has received the 31st annual Manufacturer of The Year Excellence Award by The Greater Philadelphia Chamber of Commerce.

NASA, CCAM Partner to Advance Technology & Innovation

NASA and the Commonwealth Center for Advanced Manufacturing (CCAM) in Richmond, Virginia, have joined forces to advance technology and innovation.

U.S. Aviation Industry Poised to Enter Second Golden Age

"Emerging foreign competitors are ramping up their capabilities and technological advancements in their home markets, and are even expanding their manufacturing footprint here in the U.S. in ways that will likely alter the industry's competitive landscape through this decade and beyond," said Scott Thompson, PwC's U.S. aerospace and defense leader.

IDtechEx: Electrics Will Be the Future of UAVs

The total market value for electric unmanned aerial vehicles (UAVs) will reach over one billion dollars by 2023 according to findings in the new IDTechEx report, "Electric Unmanned Aerial Vehicles (UAV) 2013-2023."

Total Avionics Sales to Exceed $1.72 Billion

The Aircraft Electronics Association announced its third quarter Avionics Market Report for this year. In the months of July, August and September 2013, total worldwide avionics sales amounted to $1,721,888,397.14, or more than $1.72 billion, as reported by the 20 aviation electronics manufacturers participating in the report.

Time for a Lean Diet

by Steve Williams
STEVE WILLIAMS CONSULTING LLC

In the drive to continuous improvement, while Lean is one of the most powerful tools available to organizations, it is also one of the most underutilized. What follows is a primer for companies considering the Lean journey.

We strive to decide our own fate. We act with self-reliance, trusting in our own abilities. We accept responsibility for our conduct and for maintaining and improving the skills that enable us to produce added value.

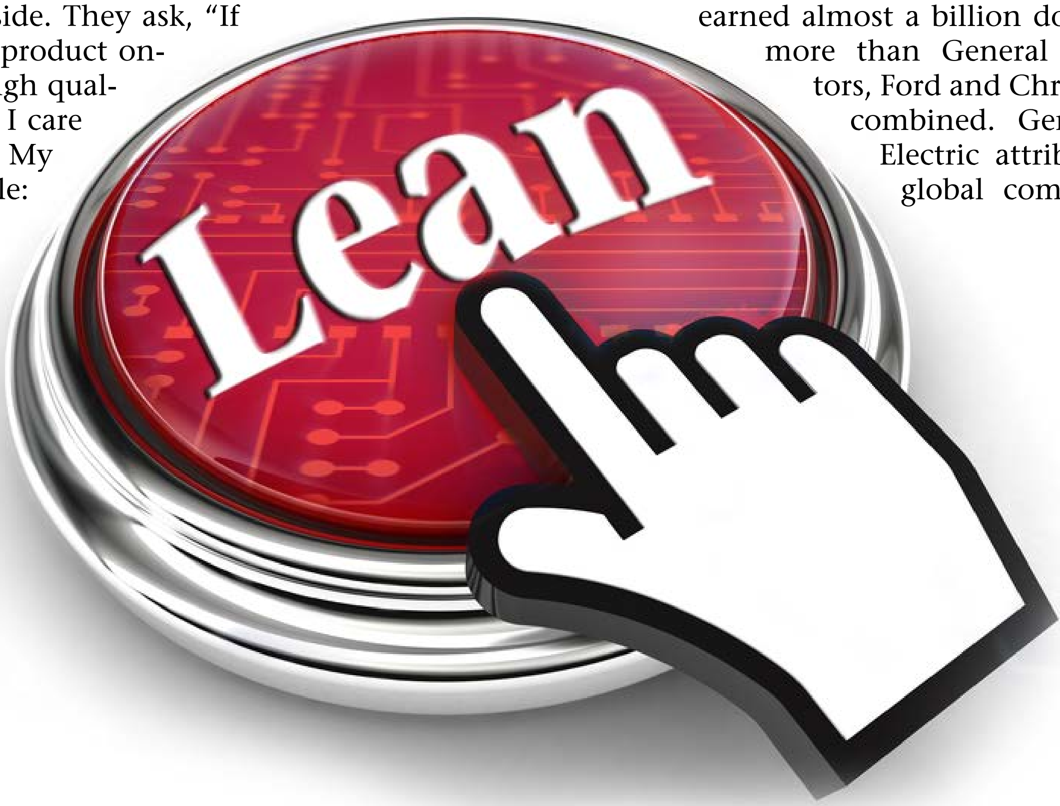
—from Toyota Motor Corporation's internal document, "Toyota Way."

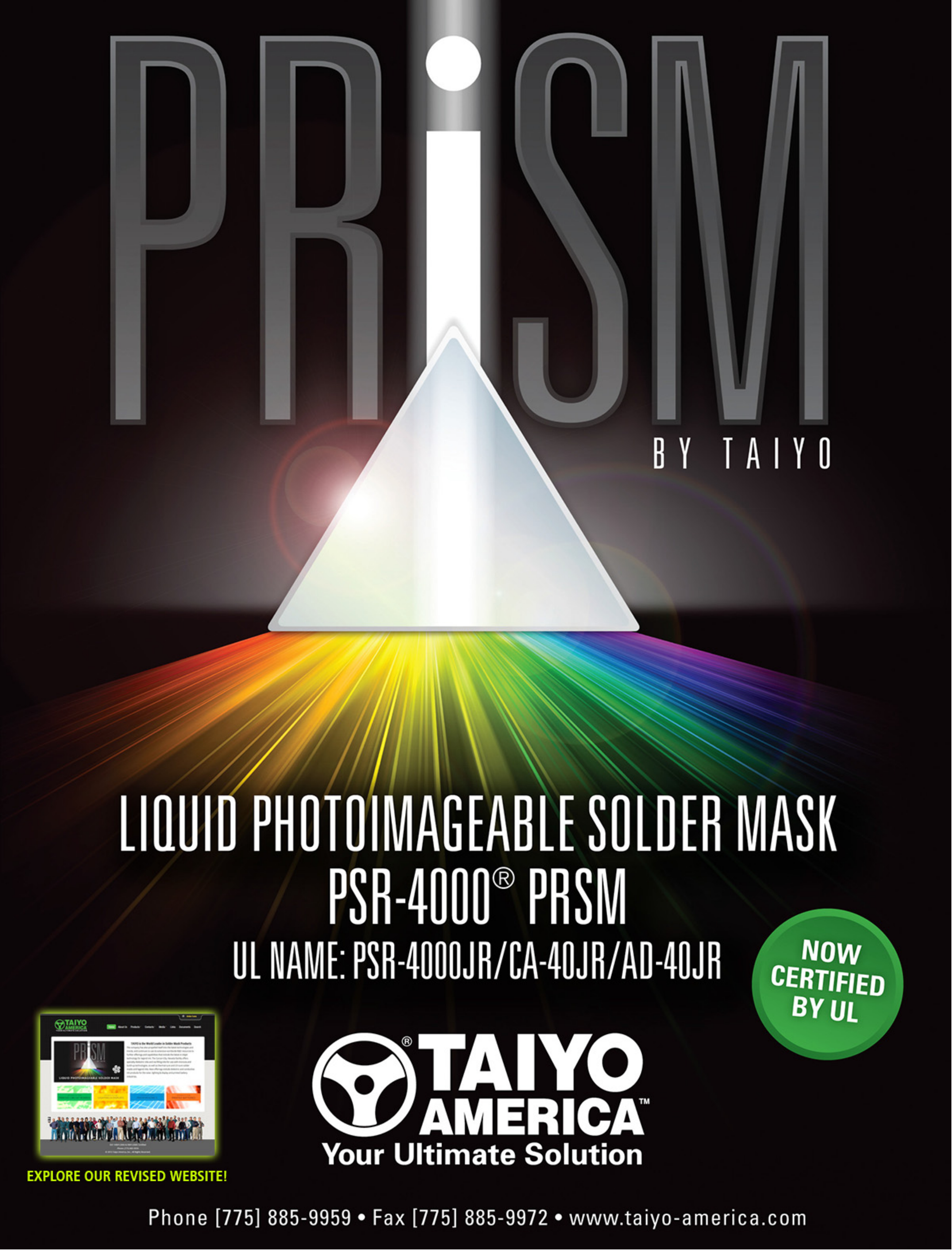
For whatever reason, PCB fabricators as a whole have yet to truly embrace the Lean manufacturing philosophy that has permeated OEM and EMS factories. My clients often push back; contending that Lean is just another "flavor of the month" quality initiative that will soon fall by the wayside. They ask, "If I am providing product on-time and of a high quality, why should I care about Lean?" My answer is simple: price and flexibility. The former is about dollars (and by the way, *it's always about the dollars*). One way or another, your customers are paying for your process inefficiencies. The latter is about lead-time. In the highly dynamic environment that we all play in today, one of the major drivers is flexibility, and the biggest constraint on flexibility is lead-time.

The opening quote captures the values and ideals of Taiichi Ohno, one of the inventors of the Toyota Way that were tasked with transforming Toyota into the world-class manufacturing enterprise that it is today. This column is intended to provide an overview of Lean and the potential benefits of it as a differentiator.

Does it work?

The short answer is an emphatic yes! Let's look at dollars (have I mentioned that *it's always about the dollars?*). In 2012, Toyota earned almost a billion dollars more than General Motors, Ford and Chrysler combined. General Electric attributes global competi-

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tiveness of their Kentucky water heater plant to Lean practices that cut cycle time by 50%, eliminated 20% of spare parts and reduced equipment investment by 30%. Allied Signal reports cost savings exceeding $800 million since 1995, and the U.S. Army has implemented Lean/Six Sigma techniques to achieve $2 billion in savings. Mining equipment manufacturer Caterpillar reduced its total global greenhouse gas emissions by 36% through Lean projects.

What is Lean?

Lean is a collection of tools and methods designed to eliminate waste, reduce delays, improve performance and reduce costs. Lean focuses on eliminating non-value added activities; as opposed to more traditional improvement efforts which focus on reducing the time in value-added steps. I would argue that Lean is not a flavor-of-the-month initiative; rather, when implemented properly, it should achieve sustainable business improvements based on verifiable financial results. Elimination of the Seven Deadly Wastes is the focus of Lean principles.

The Seven Deadly Wastes: over production, inventory, defects, transportation, waiting, over processing, and motion. All seven of these wastes relate directly to wasting dollars, and in case you don't know this, *it's always about the dollars*.

What is Six Sigma?

Six Sigma is the problem solving methodology called DMAIC (define, measure, analyze,

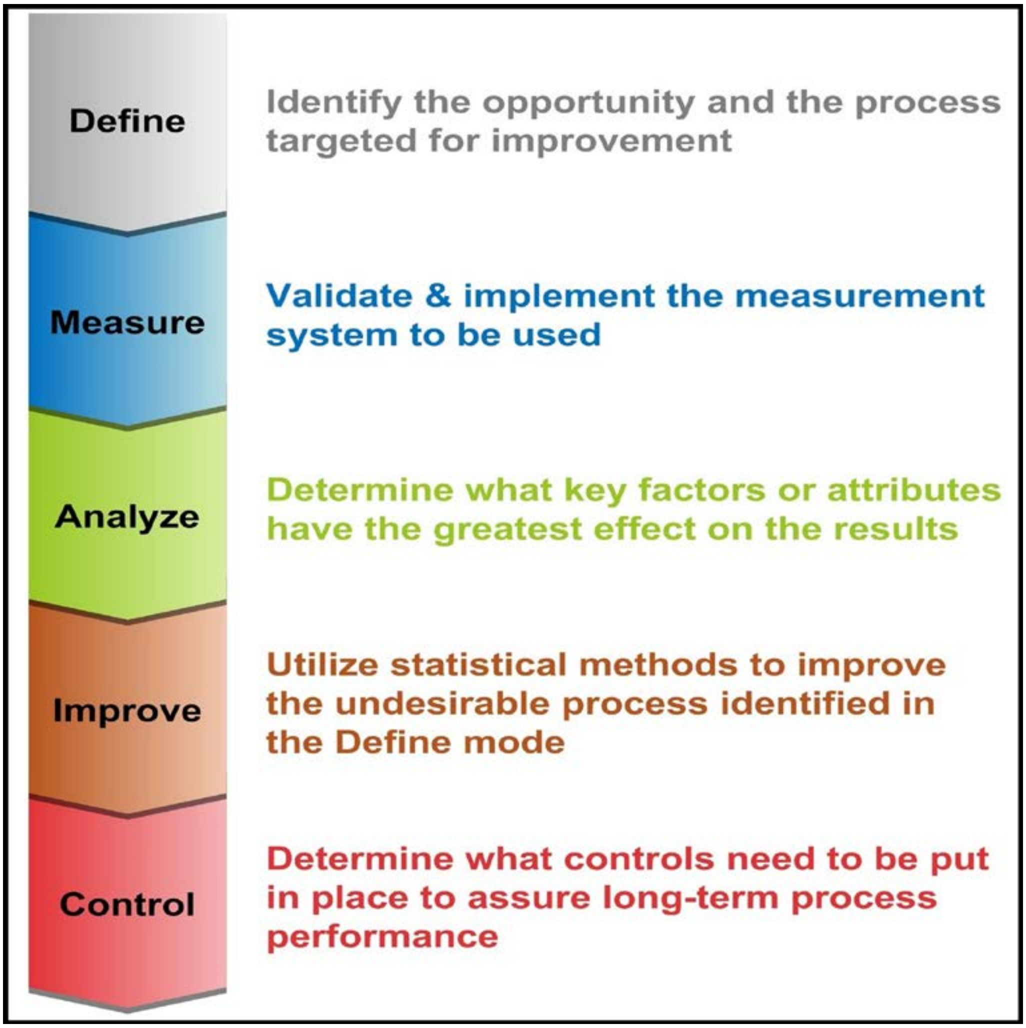

Figure 1.

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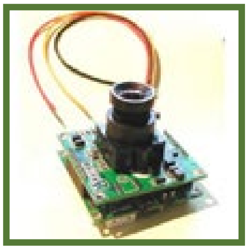

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improve, control). DMAIC is a collection of tools used to identify, analyze, and eliminate sources of variation in a process (Figure 1).

What is Lean Sigma?

Although Lean principles and Six Sigma are two distinct methodologies, they are being combined in many organizations as Lean Sigma to become a roadmap to achieving operational excellence. Some of the common tools of Lean Sigma include Cause & Effect Diagrams, FMEA, Process Mapping, Pareto Analysis, Kanban, DOE, Capability Studies, Poka-Yoke, Voice of the Customer Analysis, and the principles of Kaizen.

Why Lean Sigma?

Lean Sigma provides a consistent, quantitative problem solving methodology that can be applied across all operations, industries and businesses. This process improves the financial strength of an organization, which directly benefits the company, the employees, and the customer.

I will close by suggesting that the great Vince Lombardi's words, in his famous speech on what it takes to be number one, could also be said of Lean:

"It's not a sometime thing; it's an all the time thing. You don't win once in a while; you don't do things right once in a while; you do them right all the time." **PCB**

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

VIDEO INTERVIEW

Mentor Graphics Offers End-to-End Solutions

by Real Time with...productronica 2013

Stephan Hafele explains how Mentor Graphics has recognized and responded to the changing face of electronics manufacturing by offering a totally integrated end-to-end solution to supply chain management and control, from design through assembly.

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PCB007 Market News Highlights

November Manufacturing PMI Registers 57.3%

The PMI™ registered 57.3%, an increase of 0.9% from October's reading of 56.4%. The PMI™ has increased progressively each month since June, with November's reading reflecting the highest PMI™ in 2013. The New Orders Index increased in November by 3%, to 63.6%, and the Production Index increased by 2%, to 62.8%.

Survey Reveals Technology Investment Predictions

"CFOs continue to seek out technology which allows them to improve business performance and increase employee productivity," said Jay Cary, VP, Digital, Global Corporate Payments at American Express. "Mobile in particular is leading the way, both because of CFOs' familiarity with the technology and for the real-time benefits it offers employees."

Reliability Hinders Printed Electronics Market Growth

The major barrier inhibiting the growth of the market is the reliability of the end products (printed electronics), and it is expected that this issue will be overcome by the advancement in the functional printing technology.

Medical Automation Market to Hit $66 Million by 2018

Automated monitoring devices help in reducing rising healthcare costs, the major factor driving the growth of this market. Furthermore, growth in the use of point-of-care testing devices such as glucose meters, digital blood pressure monitors, pregnancy test kits, and HIV test kits is another factor that is propelling the market.

Total Personal Computing Systems to See 11% Growth

IC Insights forecasts total personal computing unit shipments (desktop PCs, notebooks, tablets, and Internet/cloud portables) to grow an average of 10.6%, from 2012 to 2017, reaching 770 million systems at the end of the forecast period.

Global Chip on Board LED Market to See CAGR of 40.71

One of the key factors contributing to this market growth is the declining ASP of LEDs. The Global Chip on Board LED market has also been witnessing the increasing demand of COB LED in general lighting applications. However, the fluctuating global economic conditions could pose a challenge to the growth of this market.

Functional Printing Market to Reach $13.79B by 2020

The demand for a new variety of low-cost electronic products, made possible by a range of printing techniques and materials, has pushed the demand for "functional printing" across geographies.

Conductive Ink Markets to Reach $3.36B in 2018

Conductive inks are a simple and unglamorous layer, but they will constitute a hefty $2.86 billion market in 2012. This market is forecasted to rise to $3.36 billion in 2018, with $735 million captured by new silver and copper nanostructure inks.

Consumer Confidence Continues to Drop in November

The Conference Board Consumer Confidence Index, which had decreased sharply in October, declined again in November. The Index now stands at 70.4 (1985=100), down from 72.4 in October.

Semiconductor Sales Recover in 2013; Up 4.9% YoY

Following a 2.5% decline in 2012, the global semiconductor market has regained its footing in 2013 with revenue set to expand by nearly 5% because of the strong performance of the memory sector.

Achieving Fine Lines and Spaces: Part 3: Chemical Surface Preparation

by Michael Carano
OMG ELECTRONIC CHEMICALS

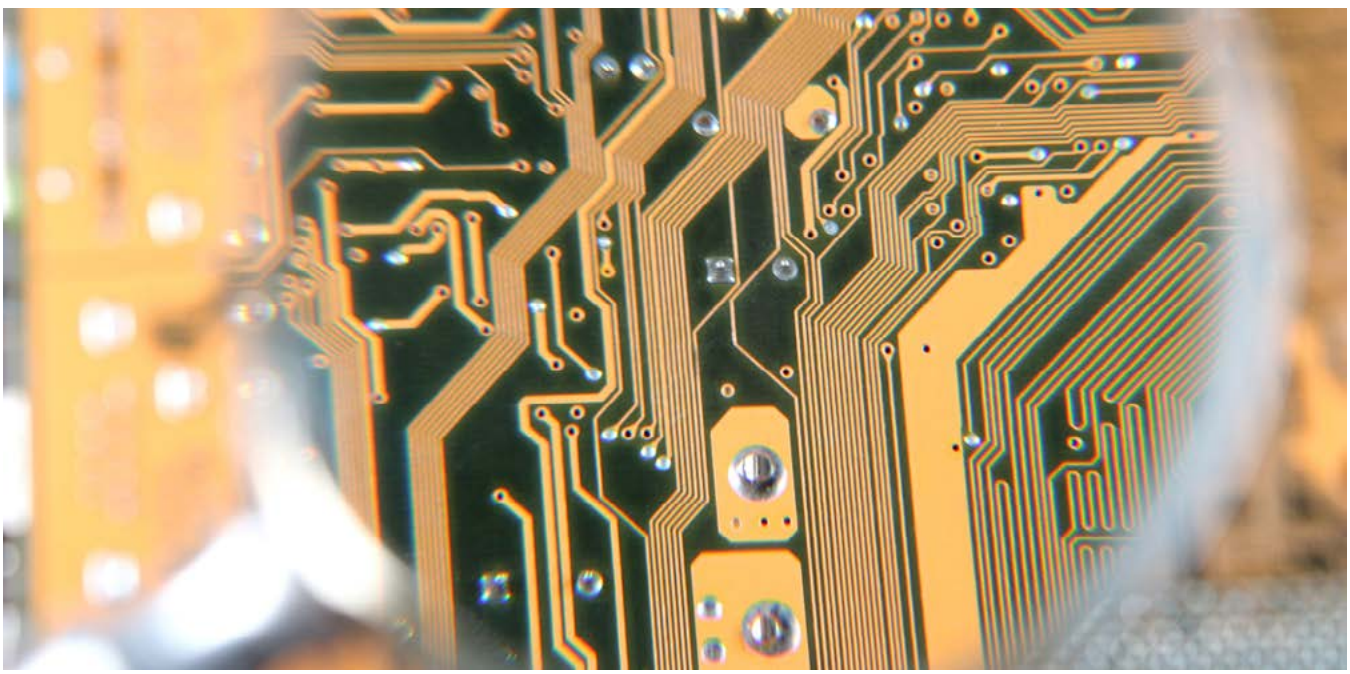
The photoimaging process is one of the first steps in the PCB fabrication process. In order to ensure that the image of the circuitry conforms as close to the desired design as possible (i.e., lines and spaces), preparation of the copper foil surface is one of the critical success factors. Employing the optimum mix of surface cleaners and microetchants will provide a clean surface with sufficient area to promote dry film adhesion. The fabricator has numerous options and should determine the optimum process by accounting for the type of copper foil used, as well as the classes of soils to be removed.

Introduction

In the last two columns I discussed pumice and aluminum oxide surface preparation. Another technique that has gained significant market share is chemical surface preparation. In this case, only chemical processes such as acid cleaners and micro-etchants are employed. However, let's first discuss the subject of the chromate conversion coating.

Chromate Conversion Coating

All copper foil and/or laminate producers process the foil through an anti-tarnish treatment that is based on chromic acid, which provides a hydrated chromate film that prevents oxidation of the copper surface. While preventing oxidation is necessary during storage, the chromate must be removed prior to micro-etching to avoid differential or step-etch during the micro-etching process. The step-etch will leave the copper surface with a non-uniform topography, which will invariably lead to less than optimum photoresist adhesion. The potential for resist to lock into some of the non-uniform areas on the foils is quite high mainly due to the extreme peaks and valleys in the surface profile. The best remedy to prevent this situation is to completely remove the chromate film.



In the past, tarnish resistance was accomplished by immersion of the copper foil into a solution containing chromate ions. Yates and other[1] further improved upon this method with an electrolytic technique to enhance the oxidation resistance of the copper foil. Still, others improved upon this invention further with the introduction of zinc chromate[2].

One should never underestimate the tenacity of the chromate film. This is precisely why I recommend a strong mineral acid cleaning step prior to pumice, aluminum oxide or chemical microetching. It is much more effective to enhance the resist adhesion when a good chromate removal process is online prior to these additional processes.

Chemical Cleaning and Micro-Etching

First, a review of various chemical cleaning methods is warranted. It is well known that the definition of cleaning is "making the soil soluble in a solvent." I don't remember who is responsible for this quote, but it is something I have not forgotten. Basically, one should under-

Cleaner class	When to use	Contraindictions	Comments
Alkaline cleaners	Use with innerlayers prior to oxide or oxide alternative processing. Will also remove light organic soils.	Will not remove copper oxides or chromate coatings.	Watch for foaming formulations as these may cause issues with cross-contamination.
Acidic soak cleaners	Can be used in spray or immersion mode. If used in spray mode, ensure the chemical is low- to no-foaming.	Will not micro-etch. May with the help of certain surfactants remove light organic soils.	Combinations of nitric, sulfuric and hydrochloric acids make excellent chromate removal chemistry. Look at individual acid formulations as well. Phosphoric acid is another good acidic cleaner.
Microetchants (persulphates, hydrogen peroxide-sulfuric, cupric chloride	Can be used in spray or immersion mode. Control copper removal with proper control of operating parameters.	Not designed to remove organic soils.	Easy to use. Some etchants can be closed-loop (i.e., recover the etched copper as a copper sulfate salt.

Table 1: Chemical Cleaners and Microetchants. Source: Idea for table from IPC document 740 (Process Effects)

stand what composition the soils are and which solvent or solvents are best suited to remove those soils. Chemical compositions designed to remove soils are endless. As an example, Table 1 below provides a summary of those processes. One should also contact the chemical supplier for advice on proper operating parameters, equipment compatibility and costs.

There are some suppliers that provide one step chromate remover/micro-etchants. Again, one should consult the supplier's technical data sheet for the proper use and indications. From my standpoint, the chemical cleaning process is more efficient and effective with at least two separate chemical steps—one as a chromate-soil remover and the second as a copper removal/copper micro-etchant.

Basic Chemical Micro-etching Processes

The basic fundamentals of chemical micro-etchants are quite simple: Remove oxides from the surface and restructure the copper foil. The latter means to roughen or create a topography for the copper that enhances photoresist adhesion without excessive copper removal. There are several key points to consider here. First, it is much more effective to create a uniform topography without excessive copper removal if the copper foil surface is already devoid of oils, soils and chromates. Thus, the first step in the surface preparation process is to provide virgin surface so that the micro-etch can perform its function. When there are soils and chromates remaining on the surface, the micro-etch will create areas on the surface that, for lack of a better term, are referred to as differential or step etch. The topography will exhibit areas of high peaks and low valleys that can promote resist lock-in. Conversely, if there are areas on the foil surface that have deep trenches in the foil due to differential etch, there are concerns with poor resist conformation (Figure 1). In this case, the resist never completely adheres to the copper in these areas. Thus there is a gap that allows for other chemicals to remove copper during the develop-etch-strip process. When other processes are able to remove the copper that was designed to be protected by the resist, the consequence is an open circuit. At the very least one will experience neck downs in the circuit traces.

With respect to micro-etchants, the two most commonly used are:

- Persulfate based (sodium or potassium)
- Hydrogen peroxide-sulfuric acid

Persulfate-based processes tend to create a much more roughened topography than does hydrogen peroxide-sulfuric acid based processes.

The angular grain structure (Figure 2) promotes sufficient adhesion of the resist to the copper surface. In Figure 3, the structure shown represents that of the copper foil that has been micro-etched by a hydrogen peroxide-sulfuric acid process. Note the differences in the structure of each. In each case, the targeted copper removal was 40–50 micro-inches. The foil is

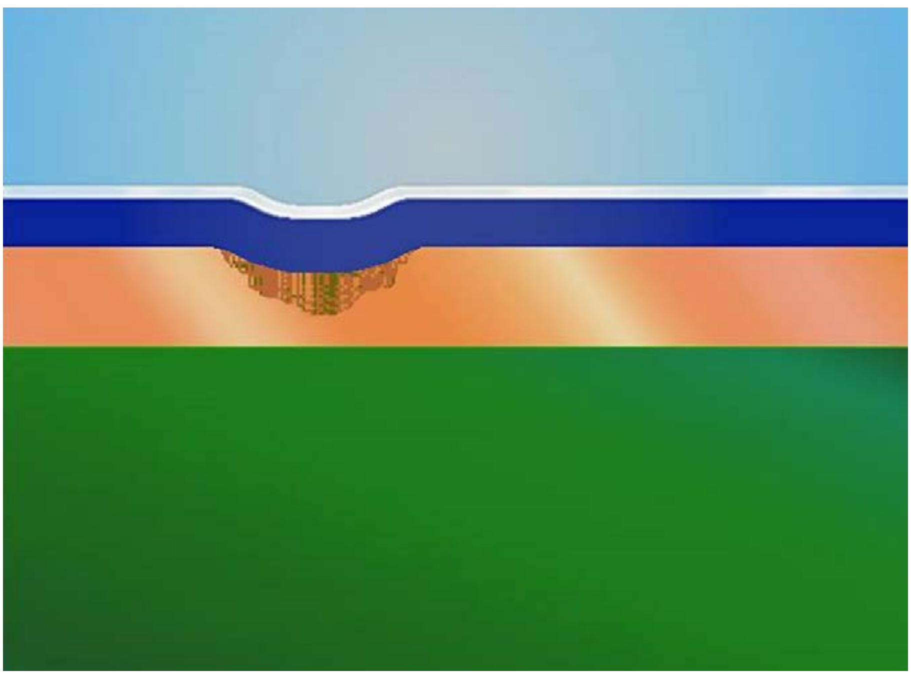


Figure 1: Poor photoresist conformation. (source: IPC)

Persulphate Microetch

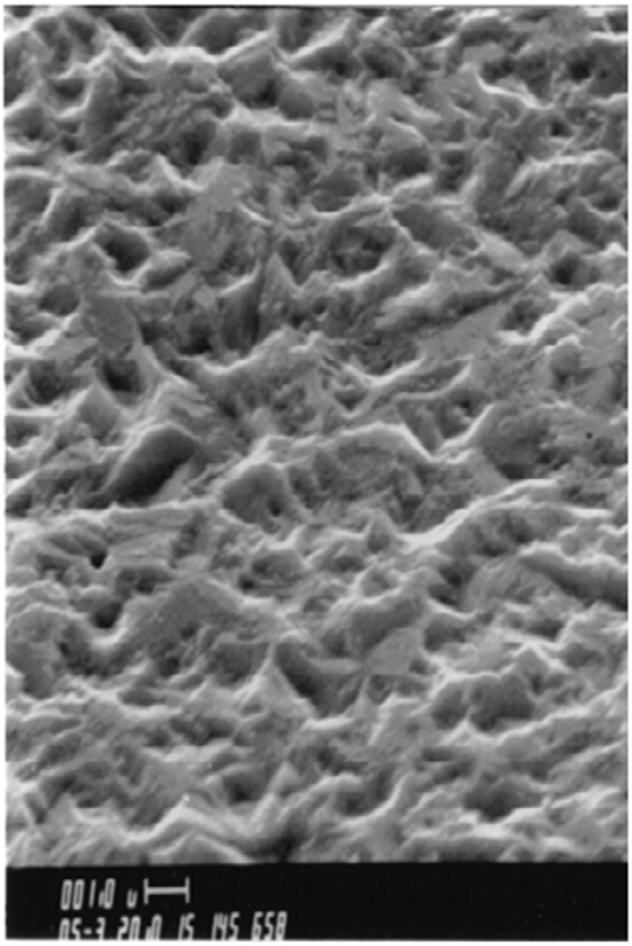


Figure 2: Structure of ED (electrodeposited foil).

Modified Peroxide Sulfuric Microetch

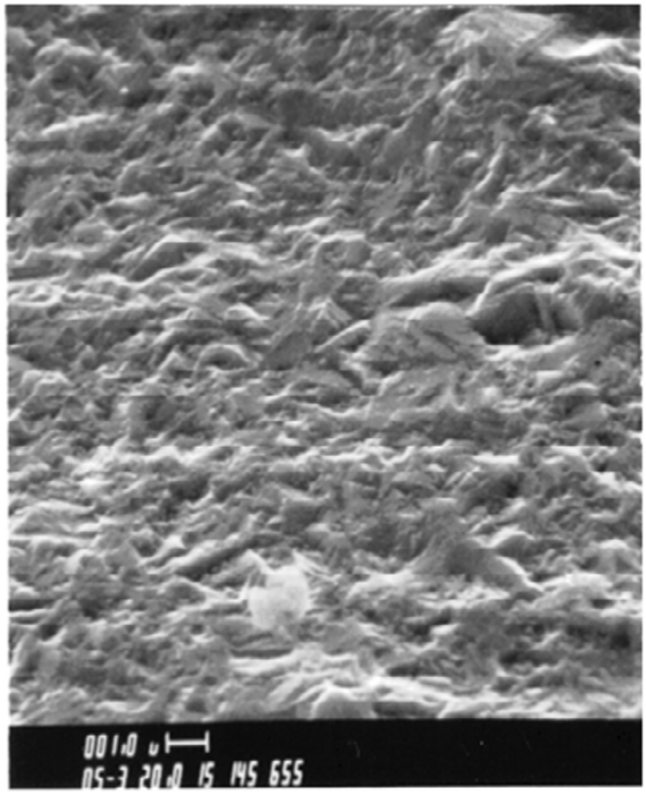


Figure 3: Structure of ED foil after treatment with hydrogen peroxide sulfuric acid micro-etchant (ED foil).

electrodeposited foil. The foil type (electrodeposited [ED] versus rolled annealed [RA]) plays a role in how the micro-etching process reacts with the foil. A closer look at the topography of RA foils after micro-etching will be presented in a future column of Trouble in Your Tank.

Summary

"Making a soil soluble in a solvent." That is a simple but accurate definition of cleaning. In the case of copper foil surfaces, this suggests that organic soils, chromate anti-tarnish coatings and oxides must be removed from the copper prior to micro-etching the foil. The former is accomplished with acid cleaners containing mineral acids, surfactants and other functional materials. Once a clean virgin copper surface is obtained, the fabricator is then able to increase the surface area of the foil with a chemical micro-etch. **PCB**

References

1. U.S. Patent 3,853,716.
2. U.S. patent 4,387,006.

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.

TOP TEN

PCB007 News Highlights This Month

1 IPC: October PCB Sales, Orders Up; Book-to-Bill Dips

"Although both sales and order growth are trending up compared to last year, sales have outpaced orders in the past three months, causing the book-to-bill ratio to dip," said Sharon Starr, IPC's director of market research. "Year-on-year sales growth has been improving for the past six consecutive months and finally turned positive in October."

2 Viasystems Opens World-class Factory in California

Designed to consolidate the sprawl of 13 buildings that used to represent DDi's PCB business, the new factory is housed in an ex-MFLEX site and was constructed from scratch. This enables the company to service its very high-end customers, both military and commercial OEMs, who are looking for the latest in HDI, high-reliability PCBs for their products.

3 PCBs for LED Lighting: The Times They Are a-Changing

BPA forecast that the market for PCBs providing enhanced thermal and power management will reach over $3.2 billion by 2020. BPA discusses some of the research in their report "Metal in the Board—Opportunities for Printed Circuits Providing Thermal and Power Management 2012-2020."

4 Wurth Elektronik: HDI Microvia PCBs Now Available

The HDI specialist Würth Elektronik has set new standards in the PCB industry: HDI microvia PCBs are now available in its online shop, WEdirekt. With just a few clicks, your HDI PCB is calculated and the price is shown immediately online. Ordering prototypes is considerably simplified and faster.

5 Canadian Circuits Acquires Oxford CMI 900 Unit

Praveen Arya, president and owner of Canadian Circuits Inc., announces that his company has acquired a new Oxford CMI 900 X-ray fluorescence coating thickness measurement system as part of the company's complete equipment upgrade.

6 PCB Solutions Offers Expanded Stocking Program

Effective in December 2013, PCB Solutions is pleased to announce offering enhancements to their stocking program. PCB Solutions is now offering a complete stocking program that enables customers to take advantage of volume pricing, but assists them with cash flow and inventory relief.

7 SOMACIS Receives Innovation Award from JDSU

At the 2013 JDSU Global Supplier Day SOMACIS received the "Excellence in Value Innovation" Award. This recognition confirms SOMACIS' focus in delivering innovative solutions through high-tech PCBs combined with co-design services.

8 Cicor Realigns from Four Divisions to Two

Cicor, an international high-tech industrial group and leader in the fields of PCBs, microelectronics, and electronic solutions, headquartered in Boudry, Switzerland, is optimizing its existing organizational structure to better align with customers' future needs.

9 Integral's Zeta Certification Awarded to Eagle Circuits

Integral Technology Inc., a manufacturer and distributor of HDI electronic materials for the PCB industry, has announced that Eagle Circuits of Dallas, Texas, has received the prestigious Zeta® Certification allowing them to produce circuit boards using Integral's revolutionary dielectric films.

10 AT&S: EmPower Consortium Aims to Optimize Energy Use

Targets include the improvement of processes for semiconductor manufacturing, development of new concepts for component packaging, and design of products for optimum management of energy.

EVENTS

For the IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For a complete listing, check out *The PCB Magazine's* full events calendar.

International Electronic Components Trade Show
January 15–17, 2014
Tokyo, Japan

Microtech Japan
January 15–17, 2014
Tokyo, Japan

Electrotest Japan
January 15–17, 2014
Tokyo, Japan

Material Japan
January 15–17, 2014
Tokyo, Japan

NEPCON Japan
January 15–17, 2014
Tokyo, Japan

PWB Expo
January 15–17, 2014
Tokyo, Japan

15th IC Packaging Expo
January 15–17, 2014
Tokyo, Japan

Lighting Japan
January 15–17, 2014
Tokyo, Japan

CAR-ELE Japan
January 15–17, 2014
Tokyo, Japan

EV Japan
January 15–17, 2014
Tokyo, Japan

DesignCon 2014
January 29–30, 2014
Santa Clara, California, USA

SPIE Electronic Imaging
February 2–6, 2014
San Francisco, California, USA

Pan Pacific Microelectronics Symposium
February 11–13, 2014
The Big Island, Hawaii, USA

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Coming Soon to *The PCB Magazine:*

Don't miss our upcoming issues!

- **February:** CAD/CAM
- **March:** Materials
- **April:** HDI

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See you next month!