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RAIG: Reduction-assisted Immersion Gold Eliminates Corrosion, Allows Thicker Deposits on ENIG & ENEPIG

Industry Experts Share Their Views:

- **Don Gudeczauskas**, Vice President, CTO
- **George Milad**, National Accounts Manager for Technology and Chair of IPC's 4552 Committee
- **Rich DePoto**, Business Development Manager
- **Patrick Valentine**, Director of Technology
- **John Meyers**, Manager, Strategic Accounts
- **April Labonte**, Senior Applications Engineer

“RAIG” answers demands for thicker immersion gold – without corrosion

Moderator: TWX-40 reduction-assisted immersion gold was introduced in 2018 as a nickel corrosion mitigation option; what has been the field experience to date?

Meyers: “From one large customer’s perspective, their Canadian facility has run ENIG for many years. They are installing the TWX-40 RAIG process because it will eliminate intermittent corrosion issues. With the continual demands on circuit boards fabrication – the way they’re built, new materials, increasing line density – the industry finally has a process that fully addresses nickel corrosion.

The fact is, this process is so unique, and has become so desirable, that is has created a strong pull into large PCB manufacturers who would not have considered changing ENIG and ENEPIG chemistries before.

A major OEM evaluated the process and created a market for this process among PCB shops. This type of ‘customer pull’ only happens a few times in a generation.

- **RAIG**: Reduction-Assisted Immersion Gold
- **ENIG**: Electroless Nickel / Immersion Gold
- **ENEPIG**: Electroless Nickel Electroless Palladium / Immersion Gold
- **EPIG**: Electroless Palladium / Immersion Gold
- **IGEPIG**: Immersion Gold / Electroless Palladium / Immersion Gold

We are now doing installs systematically at shops around the country. This speaks volumes about the advantages of UIC’s TWX-40 RAIG process.”

Valentine: “Dovetailing what John said, what I have been particularly impressed with is the distribution of TWX-40, especially at higher thicknesses. We have seen a small coefficient of variation for gold thicknesses. That is very advantageous for increasing circuit density and cost considerations. Also, being able to put a uniform coating of gold down on a very small wire-bond pad and a plated through-hole is a major performance advantage.”

Labonte: “Shops are definitely interested in TWX-40 for both ENIG and ENEPIG. Customers are continuing to push the bath’s MTOs without issue and gold plating rates have remained consistent throughout the life of the bath.”

Moderator: What changes are needed to run the process effectively?

Labonte:“The most critical requirement is a full working lab. TWX requires slightly more lab support than other immersion gold baths. Sometimes we need to assist customers in breaking bad habits, such as leaving immersion gold baths at temperature without work being processed.”

Moderator: What specific technical advantage does TWX-40’s RAIG provide compared with other options for corrosion-free ENIG and ENEPIG deposits?

Milad: "Very simply, TWX-40's reduction-assisted immersion gold gives the manufacturer the option to add more gold to the final finish layer without compromising the underlying nickel deposit. When we say 'more gold' we're looking for an increase to 3-4 microinches. These gold thickness deposits can be obtained on both ENIG and ENEPIG.

Moderator: Why would a PCB manufacturer choose a RAIG process over high phos nickel immersion gold?

Milad: "TWX-40's RAIG process provides the best protection and widest operating window against nickel corrosion. Although a correlation exists between higher phos nickel and lower corrosion, that strategy may not be totally effective.

Field performance indicates that a significant number of ENIG and ENEPIG plated layers with high phos nickel continue to have corrosion. It's Uyemura's position that, after evaluating all of the factors that affect nickel corrosion, including solution flow, pretreatment steps, plating rate, bath loading and chemical control variation, that the most reliable way to mitigate corrosion is to subordinate the immersion gold reaction and allow a reduction-assisted autocatalytic reaction to plate the majority of the deposit layer.

This strategy allows for a wider gold thickness target range. The fabricator can produce corrosion-free nickel final finish layers, consistently, with the operator skill levels that prevail in the industry."

Gudeczauskas: "In addition, the use of TWX-40 RAIG allows the nickel phos content to be kept in the middle of the range. The nickel-tin intermetallic solder joint grows faster with higher %P in the nickel. Thicker intermetallic lowers long-term reliability. Industry data suggests that longer-term solder joint reliability for high %P nickel will not be as good as for mid-phos nickel. Higher %P may well be a good option for shops that don't want to install an RAIG bath; we're looking at that for some facilities using a high phos nickel product such as our NPR-8."

Valentine: "There are several ways to mitigate hyper-corrosion. Options include modifying the electroless nickel bath stabilizer, electroless nickel bath operating parameters, rinsing parameters, or gold bath chemistry. Reduction-assisted immersion gold is where UIC is differentiated. Relying only on increased phosphorous that is not necessarily uniformly distributed within the bulk nickel may not always produce the desired corrosion mitigation effect.

Rich DePoto

This factor, combined with the different metallurgical properties of high %P nickel layers (decreased hardness, increased compressive stress, higher resistivity, poorer heat dissipation, a narrower solderability window) is what drove the development of the RAIG process.

TWX-40 RAIG also allows thicker gold deposit layers with low nickel corrosion. This allows leeway for shops that are dealing with legacy ENIG specifications of 3+ microinches of gold deposit for medical, military and other applications.

In addition, the RAIG process allows for thicker gold for ENEPIG. Thicker gold opens up the process window for wire bonding at assembly."

Moderator: Let's discuss the industry's increasing interest in ENEPIG. What makes TWX-40 an important component to successful ENEPIG processing?

Milad: "Building gold thickness on palladium is much more difficult than on nickel, and TWX-40's reduction capabilities allow this to happen much more readily. People who use ENEPIG are looking for gold wire bonding as well as soldering, and they prefer a thicker immersion gold. We say the immersion gold on palladium is in the range of 1.2 to 1.5µin, and most designers feel that even a little more gold goes a long way toward improving gold wire bonding."

Valentine: "There are definitely some electrical designs that benefit from the higher reliability of thicker gold. Gold wire bonding on ENEPIG is a diffusion bond, not an intermetallic adhesion bond. Thicker gold improves wire bond reliability."

Milad: "With thicker gold deposit layers comes improved wire bonding yield. For the people doing the bonding, higher gold increases yield. For ENEPIG, 'thicker gold ' is more than 1.5µin; between 2 and 4µin is ideal for wire bonding using ENEPIG."

Valentine: "For some end users, it comes down to wire bond pull strength. The IPC industry standard and the MIL spec require 1 mil gold wire at 2.5 or 3 gm. pull force. Some OEMs and end users want pull forces of 8 and 9 and 10 gm– 3 times over the spec. Thicker gold helps achieve that."

Moderator: Rev B has not yet been issued, so why are manufacturers addressing nickel corrosion so aggressively?

Meyers: "PCB manufacturers are trying to stay ahead of the specification. Many companies have done extensive testing and multiple corrosion studies, and when Rev A (IPC 4552) came out, they moved to get out in front of it. Quality departments were charged with

identifying where each facility ranked on corrosion and the options for addressing the issue. This is what brought the reduction-assisted alternative to the forefront. In one case, one of the divisions had already installed TWX-40 and its performance out-performed all of the other submissions. Since that evaluation, there has been no looking back in deciding which immersion gold to install."

Moderator: How are companies protecting themselves from liability re: compliance with upcoming IPC specs?

Meyers: "Liability is a major concern that PCB manufacturers know they will face. This is what drove the decision to aggressively eliminate the potential of corrosion on ENIG and ENEPIG. Consider this: the Canada facility was driven by corporate engineering, quality, and resident engineering to eliminate nickel corrosion. TWX-40 proved to be the best answer."

Moderator: Are there any credible industry voices who challenge the TWX-40 'no-corrosion' claim?

Milad: "The paper I delivered at SMTA, which will shortly be published by PCB007, outlines the TWX mitigation of corrosion in detail. As for our competitors, some have re-written history, and now claim that they 'invented' an ENIG which is corrosion-free. They have their own strategies to mitigate nickel corrosion with various nickel barriers or corrosion-resistant layers."

Moderator: Do competitors have an equivalent alternative, perhaps with a high-phos nickel strategy?

Gudeczauskas: "Increasing the phos content of the electroless nickel reduces nickel corrosion, but Uyemura does not see this as the preferred solution. The use of TWX-40 allows for NO corrosion on a variety of phos contents of deposited electroless nickel. While competitors advocate higher phos content electroless nickel to address corrosion, we view this as turning the knob on a single process parameter. The TWX-40 RAIG process provides maximum latitude on the percent phosphorous with a low-corrosion – or no corrosion – deposit."

Valentine: "I think the low coefficient of variation in gold thickness (uniformity) of TWX-40 will help process control dramatically, and is one of RAIG's most important features."

Moderator: When IPC 4552 Rev B kicks in, what will be the most immediate effect on the industry?

Milad: "Rev B will say PCB suppliers have to do a corrosion evaluation, and determine whether a sample has Level 1, 2 or 3 corrosion. It also sets forth the recommended methods for evaluation. Rev. A does not have this requirement. Unlike Rev. A, which condemns any occurrence of level 3 corrosion, Rev. B examines multiple locations and offers a method of extrapolating an overall "product rating." An occasional level 3 may not alter the acceptable product rating. This change will require PCB manufacturers to rethink their ENIG and ENEPIG strategies."

Moderator: What other capabilities does TWX-40 RAIG provide?

Meyers: "EPIG has been getting a lot of interest, particularly for high frequency applications. OEMs are running high numbers of prototype parts to address high frequency signal loss. And today, we have a job shop that already has 22 customers. Additionally, I spoke to a customer's business unit president yesterday, and he said that last week alone, they had 3 large customers who were 'begging-slash-demanding' EPIG, asap.

Now, they are branching off with future rev numbers, where they're switching from ENEPIG to EPIG. What's driving this must be a frequency loss issue. It's beyond the bickering that often goes on in the shop; it's now customer and sales-driven. This would not be happening without TWX-40's reduction-assisted immersion gold deposition on electroless palladium."

Gudeczauskas: "One of the main advantages of EPIG that I see is that it is a less complex process. When you take the nickel out, you simplify the process and absolutely eliminate nickel corrosion as a concern."

Valentine: "One consideration that can surface under certain assembly conditions is the potential for Kirkendall voids at the interface of the palladium and copper. Customers who object to any voiding even on a microscopic level need to be aware of this. In those cases where the highest reliability is required, customers should move to Uyemura's IGEPIG. This process provides the most reliable layer deposit of all the combinations."

Moderator: Are there any other major suppliers who are promoting the EPIG process?

DePoto: "Other suppliers are attempting to make inroads, but Uyemura is driving this technology. One of the major issues we face is that it's difficult to get an OEM to say 'this is what made a particular high frequency circuit possible.'

The future is clearly in high frequency designs; we just need to verify the data and the contribution of the final finish; specifically the contribution of nickel to high frequency signal loss."

DES Supplies Modern-Day California Gold Rush

Quality gold processing powers growth for Santa Ana board plater

Racking rigid panels for pattern plating

Data Electronic Services ("DES") processes ENIG, ENEPIG, immersion silver, immersion gold and hard gold, using Uyemura chemistries. In 2017, it added EPIG (also from Uyemura) to its capabilities.

Nickel, today, is what customers love to hate - and that's particularly true of the elite medical and military customers that represent the majority of DES' work. It is they who provided the impetus for the EPIG addition – a move, explains DES President Humberto Murillo, that stems from the negative effect nickel has on the signal integrity of boards used in high frequency applications.

In adding the new chemistry, DES put its quality team to work. That team, comprised of April LaBonte, Chris Carrillo, and Jeff Rand – all Uyemura tech support specialists – and DES Chemical Engineer Shailesh Vaghashia and Quality Manager Gabriela Murillo set up an in-house quality analysis system similar to what had been established for other processes. It involved XRF; atomic absorption spectrometry; solution and plated board testing, cross sectioning and photography; daily SPC charting, and quarterly audits and audit validations.

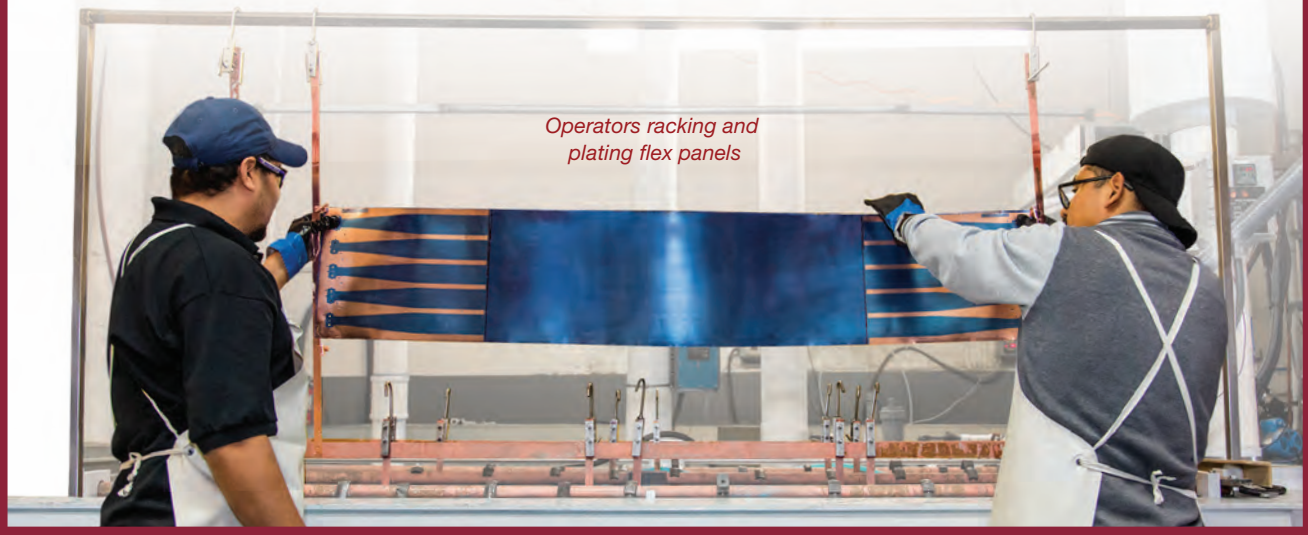
It also included several tracks of documentation: DES is ITAR compliant, holds AS9100 D and ISO 2015 certifications, and complies with IPC 4552 and 4556.

DES prides itself on its high acceptance rates, zero corrosion history relative to its gold chemistries, and compliance record. There are times when compliance takes on a different meaning, however, such as when a customer specs a gold thickness deposit that's higher than standard ENIG can achieve.

Specific instances include a program requiring not 1-2 µin, but 7 and 8µin, another for 25µin and yet another for 30 µin.

"These were boards spec'd instead for electroless gold," explains Murillo. "In close consultation with Uyemura's lab, they were manufactured to specification, using Uyemura's AuBEL 2." AuBEL Electroless Gold is an alkaline autocatalytic process with excellent gold wire bond properties, and a deposition rate of 80 µin per hour.

For heavy gold ENEPIG / EPIG applications under 8µin, DES uses TWX-40, a reduction-assisted bath that is unique in its two distinct modes of deposition, and its "zero corrosion" performance.



Operators racking and plating flex panels

Gold Rush, continued

Where traditional immersion gold exchanges with the substrate in a displacement reaction, TWX-40 deposits gold using both immersion and autocatalytic (electroless) reactions.

The autocatalytic aspect means it does not displace the substrate; it has its own driving force, and deposits gold without contribution from the base metal. TWX-40 is well documented in its ability to deposit up to 8µin of gold over palladium without compromising the underlying nickel. TWX-40 is the only immersion gold that assures compliance with IPC 4552," says Murillo.

DES worked with 3 other gold vendors in the past, changing to UIC chemistries as a solution to problems with skip plating, and to overcome objections from customers about products with a hydrochloric base, which can contaminate final finishes.

For EPIG and ENEPIG programs, TWX-40 is used with Talon 3 electroless palladium, a ground-breaking board chemistry that allows plating directly onto copper.

Inspection of surface finish board

Copper plating tank for via fill

Talon 3 deposits an electroless / autocatalytic palladium that is solderable and gold wire bondable. The bath has a low palladium metal content and is highly stable; the rate of deposition and quality of the deposit are consistent throughout the product's bath life. The EPIG finish produced with Talon 3 electroless palladium solders perfectly after eight hours of steam aging – a notable benchmark.

This nickel-free alternative process is widely predicted to become more consequential as lines become tighter, space more critical, and high frequency applications more common.

DES has major plans for 2020, including a return to electrolytic soft gold, a process that had been offered previously, then discontinued. DES's first priority, though, is the start-up of a plasma system to augment its desmear cleaning operation. Plasma is the most effective means to enhance interface adhesion, remove oxides and prevent micro-voids between layers during electroplating. "Also," explains Murillo, "our boards often have via holes, rather than through-holes, and the former can only use plasma. This will allow us to process vias, and holes less than 8 mil."