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Heavier Gold? Industry Experts Weigh-in

One of the most contested – and contentious - issues in board manufacturing today is customer demand for heavier gold as the final step in the ENIG/ ENEPIG process.

In this roundtable discussion, 5 industry experts from UIC, each with a very different perspective, share their views.

The participants were:

- **Don Gudeczauskas**, Vice President, CTO
- **George Milad**, National Accounts Manager for Technology and Chair of IPC's 4552 Committee
- **Rich DePoto**, Business Development Manager
- **Jeff Rand**, Regional Sales Manager
- **April Labonte**, Senior Applications Engineer

Uyemura Central Research Laboratory

TWX-40 was developed by the Uyemura Central Research Laboratory, Hirakata, Japan, one of the world's most prominent R&D facilities devoted to surface treatment.

"CRL" has specialized divisions for final finishes, electroless copper, acid copper, metal finishing, equipment and controls. Some of its more notable achievements include Electroless Palladium, Immersion Gold (EPIG); KAT Electroless Nickel/ Immersion Gold (ENIG); TWX-40 mixed reaction bath, which delivers both immersion and autocatalytic modes of deposition; EPITHAS™ Ni/Au Process for Under Bump Metallization on aluminum / copper; a CMOS-compatible UBM for Silicon / SOI Wafers; Presa RMK-25 Immersion Tin for backplane and other press fit applications, and RGA Immersion Silver.

> *A half-century ago, CRL was founded as an institution for interdisciplinary research on surface treatment. Since then, our work especially with final finishes and copper plating products, both electroless and electrolytic, have been highly acclaimed, and the globalization of our activities has gained the respect and patronage of companies worldwide.*
>
> *– Don Gudeczauskas, Vice President, CTO*

EVF-R Void-free Blind Via Fill

EVF-R is a unique DC copper plating system that fills blind vias 30-145 microns at unprecedented speeds with less than 15% dimple. Notably, it eliminates center voids, which, while permitted by IPC specs, are unwelcome.

EVF-R was created for aspect ratios of 1:1 or less. With current-time adjustment, it also plates ratios where depth exceeds the ablated hole diameter.

EVF-R's organic additives rarely require regeneration. The chemistry benefits from unique solution dynamics: the leveling component suppresses plating at the surface while brightener and carrier accelerate plating at the bottom.

EVF-R is a robust, high-copper low-acid process that's ideally suited to sequential architecture and HDI boards.

Uyemura leads the industry in via fill technology. Also available: EVF-N for blind via diameters less than 150 µm, and EVF-YF-4. Both simultaneously plate through-holes and blind vias.

Heavier Gold?
Industry Experts Weigh-in

Moderator: Let's start at the beginning. What was the impetus behind the demand, and what applications were thought to benefit most?

Don: The standard deposit for ENEPIG has historically been 1-2 µin of gold. Many customers now consider this insufficient, and designers are routinely seeing specifications for a minimum 3-5 µins gold. A thicker gold deposit on ENEPIG is seen as a way to enhance wire bonding to the finish, while preventing damage to the nickel underlayer.

George: Regarding applications, heavier gold is most often specified where there is a possibility of atmospheric corrosion.

Rich: Yes, in harsh environments – both extreme temperature and also 'light pollutant' environments - thicker gold is more robust, maintaining high solderability and low contact resistance.

Moderator: So shops have responded to the demand for heavier gold – how?

Rich: To get thicker deposits, shops have increased dwell time in the immersion gold. But with even minor porosity in the palladium layer, the immersion gold process aggressively attacks the underlying nickel. The result was that wire bonds lift, and press pin connections became unreliable at the palladium-nickel interface.

Moderator: So what are the alternatives ...

Rich: ... the classic alternative is to deposit autocatalytic gold over immersion gold. This produces a thick deposit, but adds a processing step – and drives up costs.

In 2015, Uyemura brought to the US an entirely new technology for achieving thicker gold, a mixed reaction electrolyte called TWX-40. Developed by the Uyemura Central Research Lab in Hirakata, Japan, TWX-40 is a single immersion gold bath with autocatalytic capabilities that deposits 4-8 µin gold in a single step. The unique reduction-assisted reaction of TWX-40 allows shops to autocatalytically keep depositing gold ions, facilitating fast gold build-up and shorter dwell times, without a corrosive replacement reaction. For ENEPIG shops serving a diverse customer base, it has become an excellent solution, supported by what is now a solid track record.

Moderator: My sense is that the advantages of a single immersion gold bath with autocatalytic capabilities are not universally understood.

George: Yes, one major advantage is you can integrate this chemistry into an existing line without adding tanks. The alternative, thin immersion followed by electroless gold, requires two tanks. With TWX-40, the single-step immersion gold process takes over. This is a big advantage, because for any shop, a gold bath is a major investment.

Jeff: In my view, the most important factor is that this is the lowest corrosion bath on the market.

George: I agree. The more the industry calls for corrosion-free, the more TWX is at the forefront. The IPC is working in that direction, evaluating and trying to minimize corrosion. We're also discovering there is nickel corrosion on product using ENEPIG, which wasn't on anyone's horizon. ENEPIG was supposed to be corrosion-free. We are taking up this issue at IPC. We have stated in the committee that we have seen corrosion of the nickel in ENEPIG, and want to begin addressing that.

Rich DePoto

George Milad
Don Gudeczauskas

April Labonte
Jeff Rand

Minimizing nickel corrosion is so critical; I'm glad Jeff put it in perspective. When depositing immersion gold on palladium, the reaction is difficult and a mixed reaction bath like TWX-40 is capable of depositing on both a palladium substrate and a nickel substrate. Immersion gold reactions on palladium are slow, and you need a chemistry like TWX if you're going to attempt to deposit immersion gold on a palladium surface. And that brings EPIG into the conversation.

EPIG is gold on palladium. ENEPIG is gold on palladium, but the bigger problem with ENEPIG is we're seeing corrosion under the palladium. With ENEPIG, you focus on corrosion, and with EPIG you focus on the capability of the bath to readily deposit on the palladium substrate.

Moderator: Can we discuss a little more about the metallurgy of the 2 common alternatives for building heavy gold?

George: We know that various manufacturing sites have attempted to deposit thicker gold using strictly immersion baths and they have run into corrosion problems. TWX-40 is more forgiving than standard immersion gold; it does not allow corrosion to occur.

Jeff: My experience is that the TWX-40 reaction goes from immersion to autocatalytic very quickly, arresting the corrosion process before it can begin.

George: I like to say that both reactions start simultaneously and as the substrate is covered with gold, the immersion reaction ability becomes less and less. As the immersion reaction slows down due to unavailability of the nickel substrate, the auto-catalytic reaction takes over and continues. Do you see a problem with this logic?

Don: Once the seed layer of gold is deposited on the surface of the feature, the chemical reduction part of the reaction kicks in, as fewer sites for nickel became available for immersion plating, the only thing left for depositing is the autocatalytic part of the reaction from TWX-40.

George: So can we say that the autocatalytic reaction does not kick in until there is a gold substrate from the immersion reaction?

Don: It only takes a very thin amount of gold – a few atoms thick - to start.

George: OK, so the easy way to explain it is: both reactions start together ... the immersion slows down, the autocatalytic reaction continues at the same rate. One rate of deposition overtakes the other, seam-lessly, as the substrate is covered.

Moderator: What operational aspects are worth consideration?

George: Automatic replenishment of chemistry is important.

April: Yes, there's a PLC-based controller for auto-dosing that's activated by bath temperature. It's applicable to both immersion or autocatalytic baths, and is the only one on the market.

Jeff: With any installation, tank design is going to be critical - along with solution movement around the heater, whether by eductor, or pneumatic mixer.

Jeff: We haven't mentioned yet that TWX has a faster deposition rate than typical immersion gold. If the goal is 3 microinches for example, TWX plates significantly faster over a palladium substrate– and at a lower temperature.

Don: I want to emphasize that TWX-40 is a highly beneficial component for ENIG as well as ENEPIG. In the same manner as described, it has the capability of depositing gold directly onto nickel with no corrosion and with a faster plating time.

George: TWX has significant advantages over every immersion gold – including all of ours. For a nickel surface, it is the most gentle bath, as well, since the autocatalytic reaction does not create corrosion.

Moderator: Is there a cost premium between traditional immersion golds and TWX-40?

Don: The main cost component for all gold baths is the metal itself. TWX-40 has a slight premium to some others, but it is not significant, given its operational advantages.

Moderator: Is there a difference in deposit uniformity between a traditional immersion gold, such as UIC's TAM-55, and the reduction-assisted TWX product?

George: Deposit uniformity for the reduction-assisted process is at least theoretically better than traditional immersion gold, depending on the shape of the pads. Larger pads attract less gold, but the autocatalytic process is not as partial to pad size. **[see chart right]**

Jeff: We can also say that the autocatalytic TWX has a tighter grain structure than immersion gold. Customer tests show that.

	Competitor A Immersion Au			Competitor B Immersion Au			TWX-40 MIXED POTENTIAL			Competitor C Immersion Au		
Pad Area	**Mean**	**Std Dev**	**CoV**	**Mean**	**Std Dev**	**CoV**	**Mean**	**Std Dev**	**CoV**	**Mean**	**Std Dev**	**CoV**
0.00090	2.53	0.13	5.13	2.50	0.23	9.27	2.88	0.11	3.86	2.27	0.19	8.24
0.0016	2.52	0.13	5.33	2.48	0.23	9.35	2.88	0.10	3.62	2.22	0.15	6.92
0.0025	2.51	0.15	5.93	2.45	0.22	9.11	2.87	0.08	2.80	2.18	0.14	6.56
0.0036	2.48	0.17	6.69	2.40	0.19	7.89	2.84	0.07	2.45	2.16	0.14	6.28
0.0064	2.48	0.17	7.04	2.37	0.20	8.27	2.84	0.07	2.38	2.14	0.12	5.72
0.1675	2.31	0.30	13.00	2.22	0.25	11.20	2.85	0.05	1.81	2.02	0.14	6.81
Range	0.22	0.17	7.87	0.28	0.06	3.31	**0.04**	**0.06**	**2.05**	0.24	0.06	2.52

All units of measure are in micro-inches; pad area in square inches.

Note: *according to Pat Valentine, UIC's Manager for Lean, Six Sigma & Continuous Improvement and a Six Sigma Master Black Belt, TWX-40 has better uniformity than a typical immersion gold production bath. The table above summarizes the results of a study comparing Au thickness versus pad size for different gold baths. The important metric is the CoV (coefficient of variation) value, which is a measure of the spread of variation in a data set relative to its mean. CoV is a unit less scale, which allows one to compare the variation in data sets that have different means. Correspondingly, the smaller the CoV, the tighter the data distribution. The CoV in this case is lowest for TWX-40 and is driven by its mixed potential / autocatalytic reaction which does not discriminate relative to pad size.*

Rich: Yes, we have run empirical testing on resistance to etchants, specifically looking at time exposed to ferric chloride. TWX-40 shows no etchant penetration after 30 minutes exposure. Whether that is the result of a finer grain structure, or thicker, non-porous gold is a question.

Jeff: The appearance of TWX-40 gold is better than immersion gold on palladium – or anything out there. It's brighter.

George: Immersion gold on palladium is pale; TWX is a much richer color.

Jeff: It has been a nice surprise for a customer when he notices that.

Rich: I'd like to discuss the major complaints customers have regarding ENIG, and final finishes overall. What are new customers – or prospective customers - asking us to do, or solve?

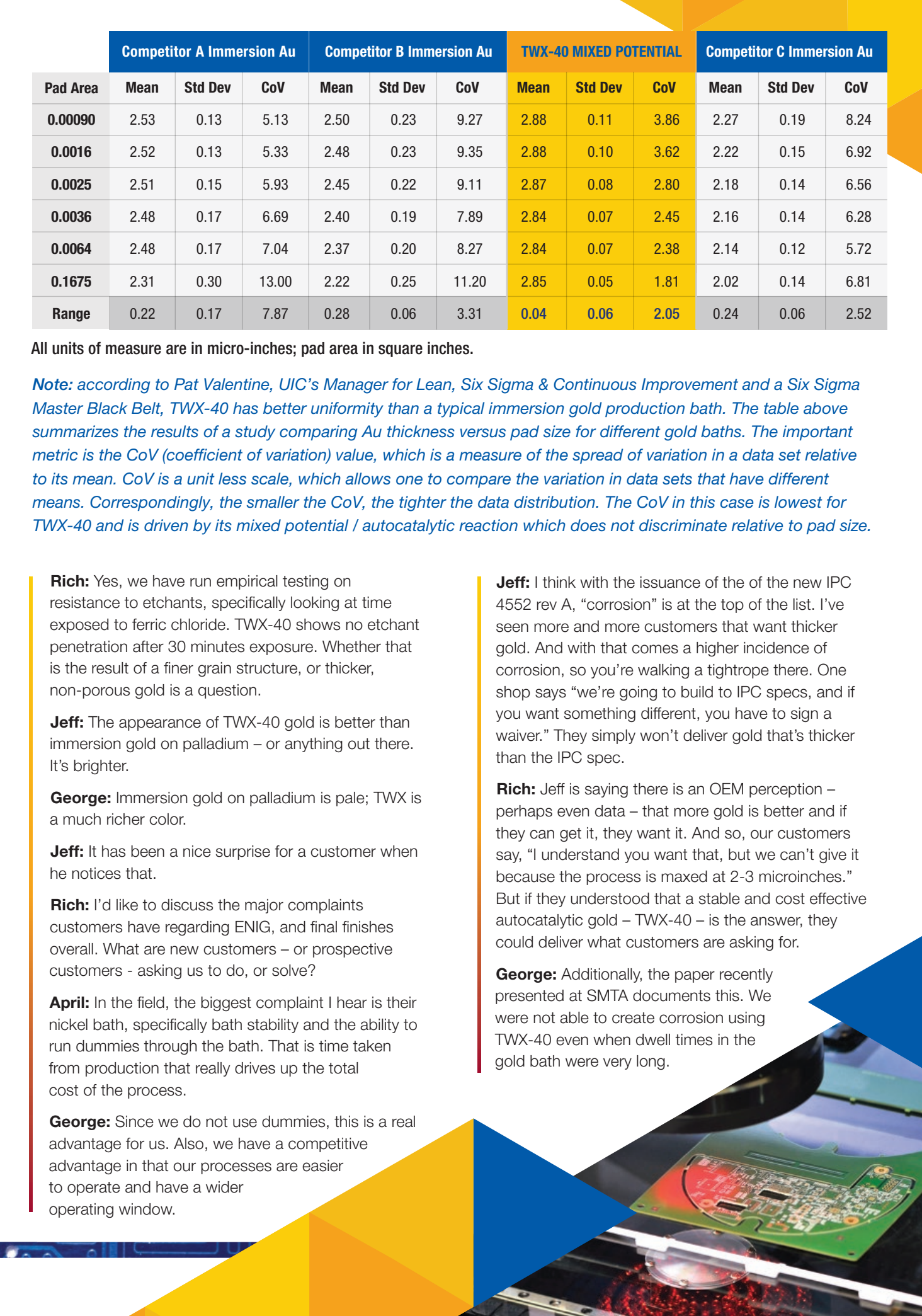
April: In the field, the biggest complaint I hear is their nickel bath, specifically bath stability and the ability to run dummies through the bath. That is time taken from production that really drives up the total cost of the process.

George: Since we do not use dummies, this is a real advantage for us. Also, we have a competitive advantage in that our processes are easier to operate and have a wider operating window.

Jeff: I think with the issuance of the of the new IPC 4552 rev A, "corrosion" is at the top of the list. I've seen more and more customers that want thicker gold. And with that comes a higher incidence of corrosion, so you're walking a tightrope there. One shop says "we're going to build to IPC specs, and if you want something different, you have to sign a waiver." They simply won't deliver gold that's thicker than the IPC spec.

Rich: Jeff is saying there is an OEM perception – perhaps even data – that more gold is better and if they can get it, they want it. And so, our customers say, "I understand you want that, but we can't give it because the process is maxed at 2-3 microinches." But if they understood that a stable and cost effective autocatalytic gold – TWX-40 – is the answer, they could deliver what customers are asking for.

George: Additionally, the paper recently presented at SMTA documents this. We were not able to create corrosion using TWX-40 even when dwell times in the gold bath were very long.



Heavier Gold?
Industry Experts Weigh-in, continued

George: We have spent years convincing customers not to put too much gold down because of corrosion concerns. But they want it anyway, to some degree it's performance driven and now we can do it without the corrosion. This is an important transition scenario.

Rich: I do see it as a pivot, but not as sharp or difficult a pivot as I once thought. I do think there are valid reasons, and now with higher complexity and expanding assembly processes being used, thicker gold offers performance advantages. An example is, as ENEPIG has steadily grown, it has actually been very difficult for PCB suppliers to meet some of the (IPC) minimum thicknesses of gold. Often, suppliers have had to be adaptive and forced to use extended immersion gold dwell times.

Don: I want to also talk about the nickel process, specifically, why customers are switching to us. First, NPR-4 nickel, especially, is very tolerant of abuse, doesn't plate-out, and performs well under a variety of circumstances.

April: A major reason customers change to our chemistry is the robustness of our nickel bath, and its ease of operation.

Moderator: Let's clarify what we mean by "robust." Are we referring to chemical stability, or something else?

April: By robust, we mean the bath can tolerate a lot of abuse; it's a 'workhorse' bath that runs easily with the controller.

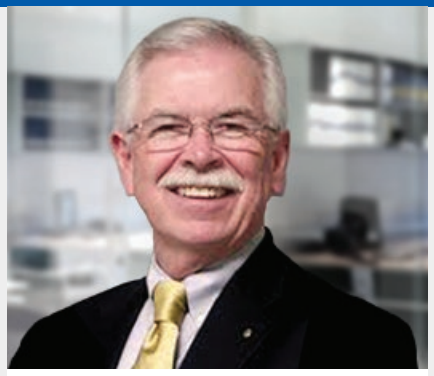
George: "Robust" also means that it produces the same product after 1 metal turn-over- or 10, or 20 - and is contamination-tolerant. And it does not contaminate as readily. Robust nickel is critical to corrosion control.

George: Yes, and the paper recently presented at SMTA documents that. We were not able to create corrosion, even when dwell times in the gold bath were very long.

Don: It also doesn't present issues with thin plating on the shoulder.

Jeff: I would like to add something - right now, we're setting up a customer with a VDS – we are the only ones in the market with a Volumetric Dispensing System. It is simple to operate, and provides better control without reliance on pumps for chemical additions.

Don: This customer regards it as the 'cat's meow' for control of the bath. Not sure if we should use that, but that's a direct quote.



Uyemura, its Industry Partners, Customers and Suppliers Congratulate **Tony Revier** on his **30th Anniversary** as Uyemura President and CEO.